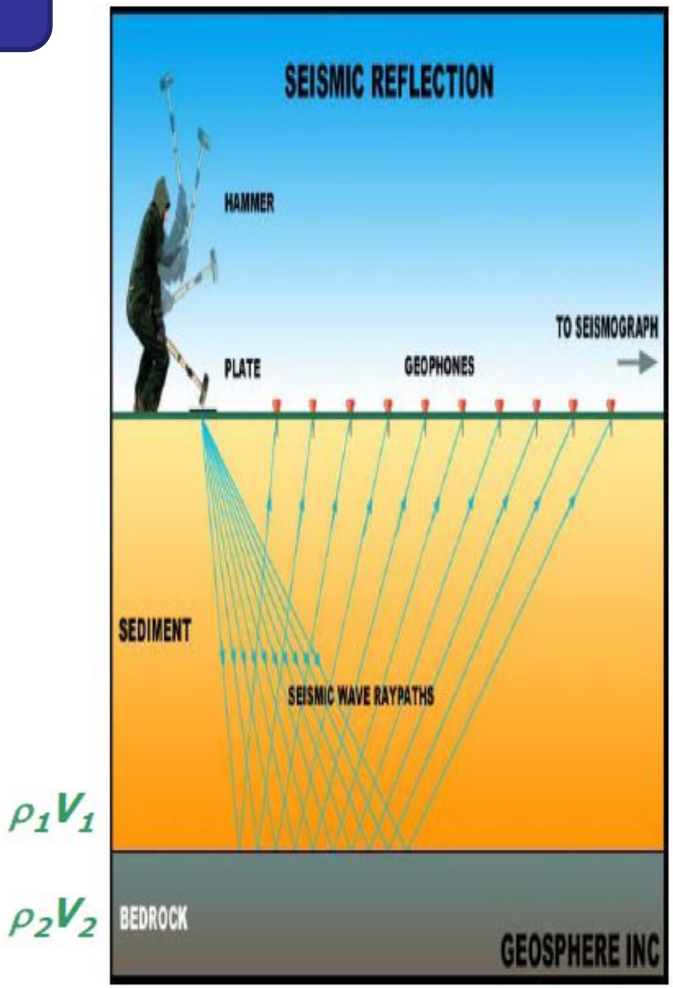
# Метод отраженных волн.

- Чувствителен к границам на которых происходит изменение акустического импеданса.
- Используются, в основном, продольные волны.

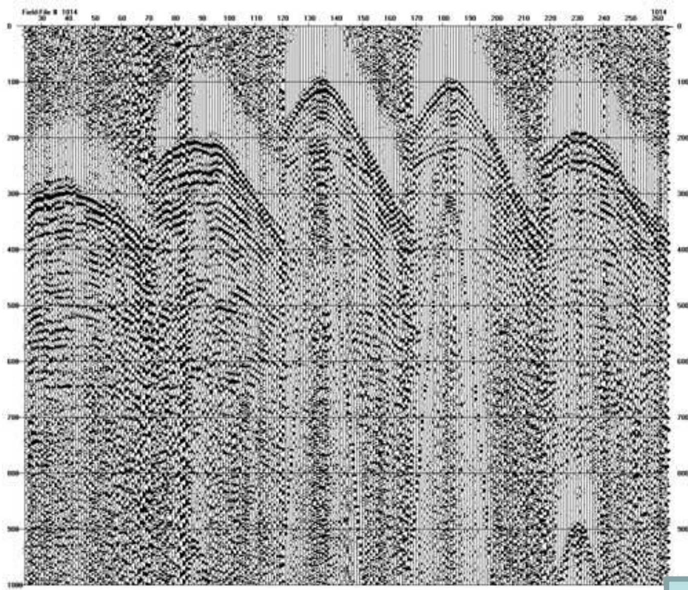
Масштабы объектов

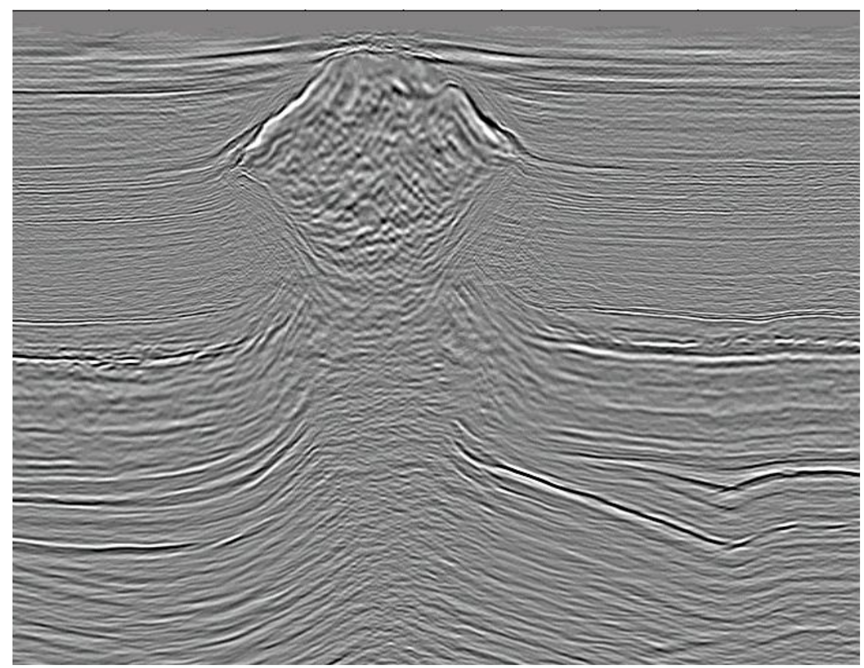
- 10'ки метров - инженерные задачи.
- Первые километры – разведка МПИ.
- 10'ки километров – структура коры.



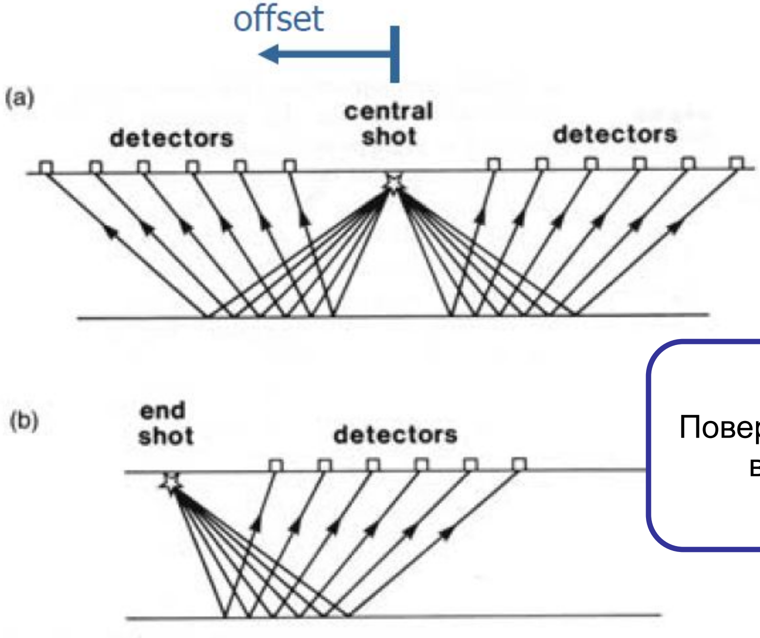
**Задача разведочной сейсморазведки.**

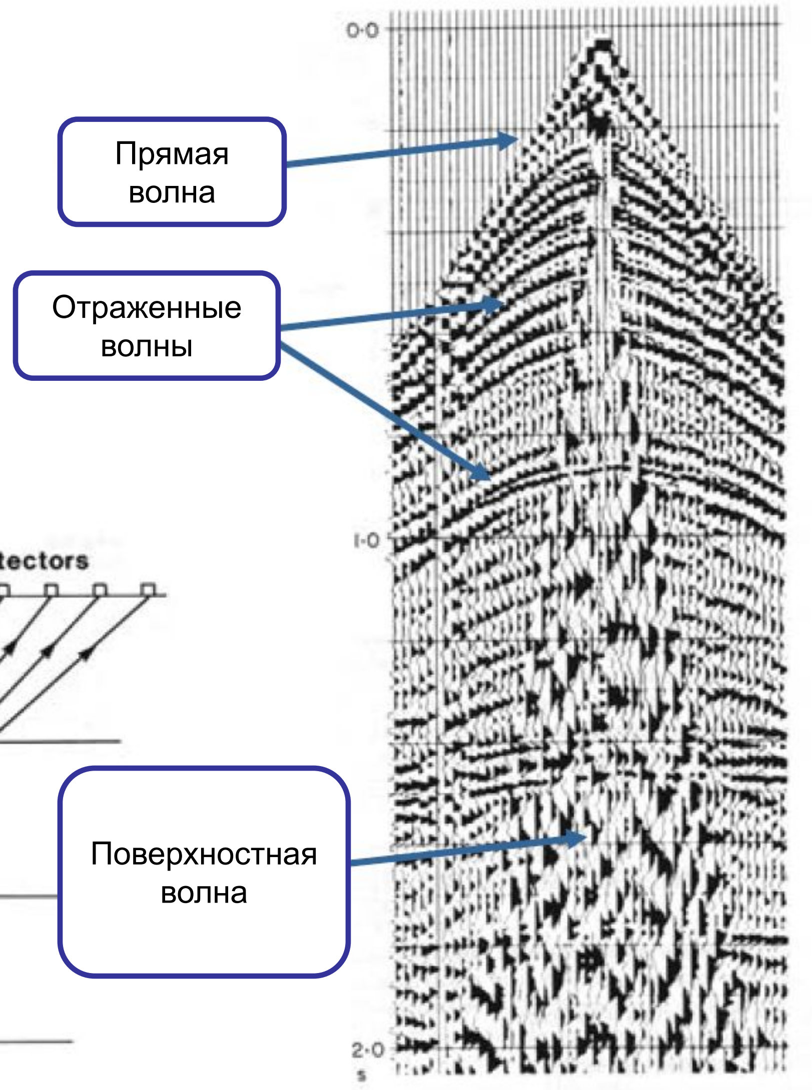
- Спроектировать систему получения данных.
- Получить данные.
- Обработать и получить сейсмический разрез.
- Извлечь и представить максимум информации
   для данных и соответствующего разреза.





# Выборка ОПВ


offset
(a)
detectors
central
shot
detectors
(b)
end
shot
detectors


Прямая
волна
Отраженные
волны
Поверхностная
волна
0·0
1·0
2·0
s

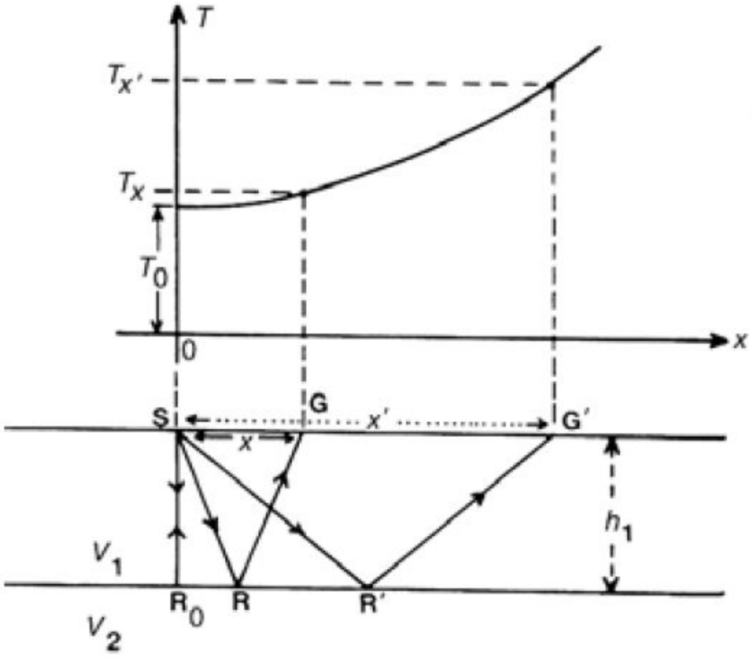
# Годограф отраженной волны. Кинематическая поправка.

В случае одной горизонтальной границы, годограф отраженной волны имеет вид:

$$T_x = \frac{2SR}{V_1} = \frac{2}{V_1}\sqrt{h_1^2 + \left(x/2\right)^2}$$

или

$$T_x^2 = T_0^2 + \frac{x^2}{V_1}$$




**The arrival time curve is a hyperbola**

Исследование времен прихода волн в чистом виде относится в сейсморазведке к кинематической задаче.

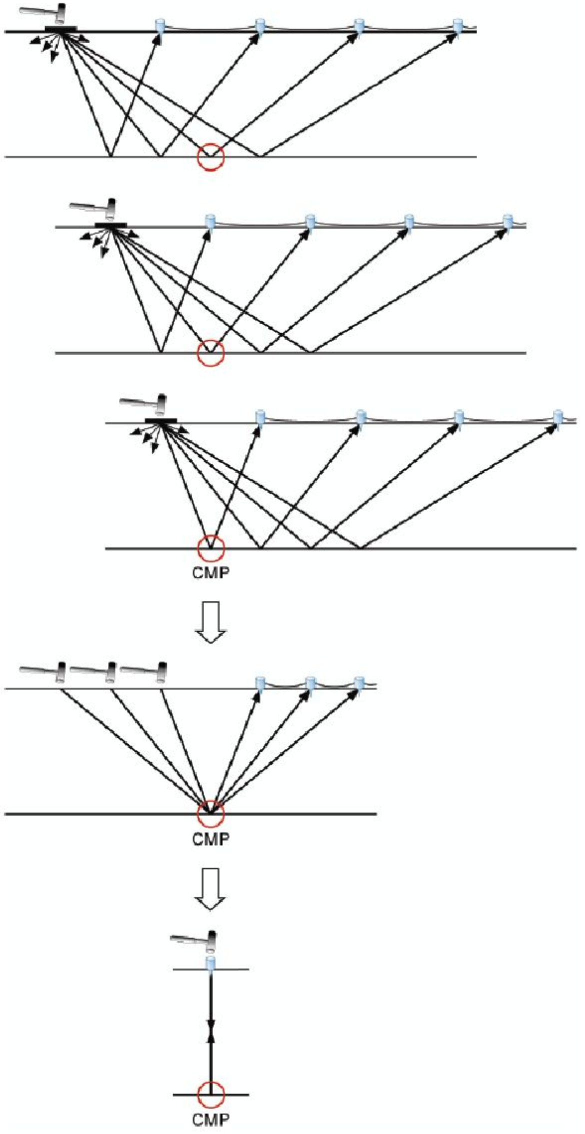
Годограф для наклонной границы

# Выборка ОСТ (осуществление)

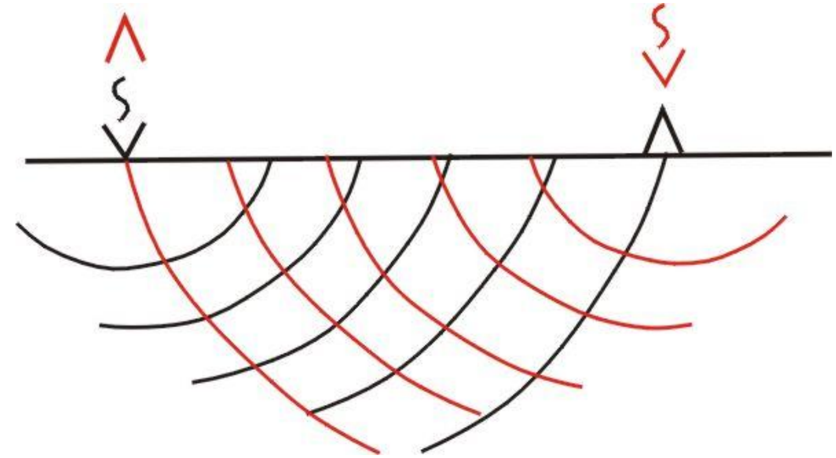
Sequentially move shot and
receiver string across the surface

Кратность – Количество трасс в выборке ОСТ.

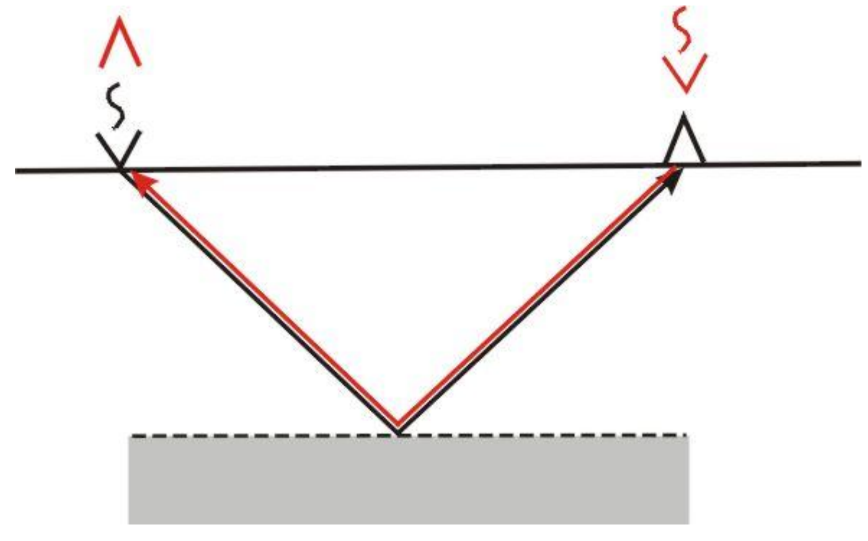
Типичные значения – около 6 для инженерных работ . 20-50-100 и более для нефгазотеразведочных



# Принцип суперпозиции, принцип взаимности



- Принцип суперпозиции: при интерференции (наложении) нескольких упругих волн, их распространение можно изучать независимо для каждой волны.



- Принцип взаимности: если поменять местами источник и приемник, то время прихода сигнала, форма лучей и характер колебаний частиц геологической среды не изменятся.

# 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**

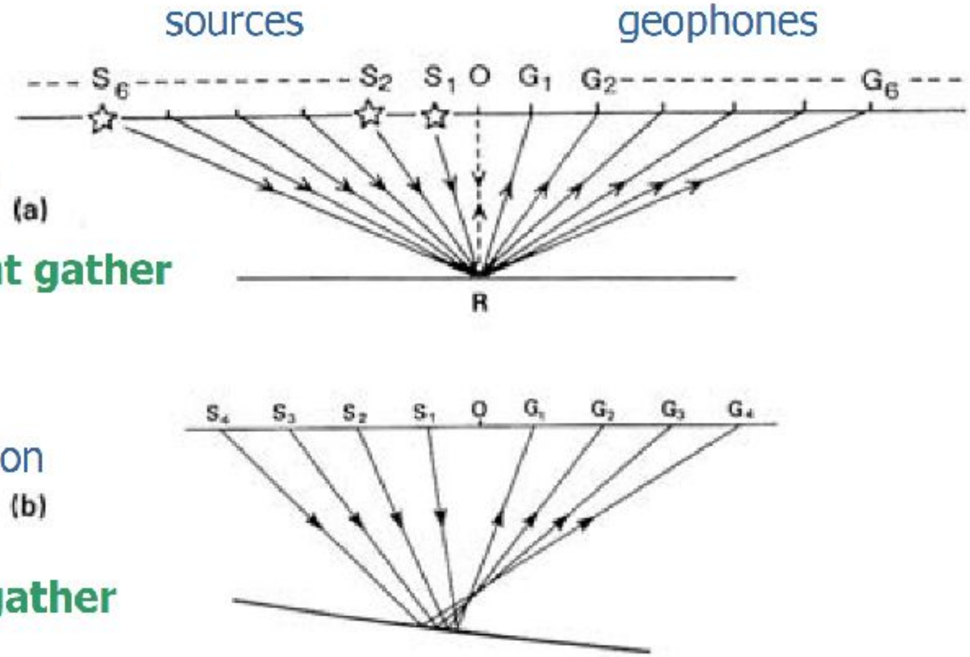



Fig. 4.16 (a) Ray paths of reflections belonging to the common-depth point (CDP) which is located below the shot–geophone common midpoint, O. The arrangement shown gives a six-fold coverage of the subsurface reflection point, R, on a horizontal reflector. (b) For a dipping reflector, the reflection point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

# Normal move out (NMO) correction

The reflection traveltime equation predicts a hyperbolic shape to reflections in a CMP gather. The hyperbolae become fatter/flatter with increasing velocity

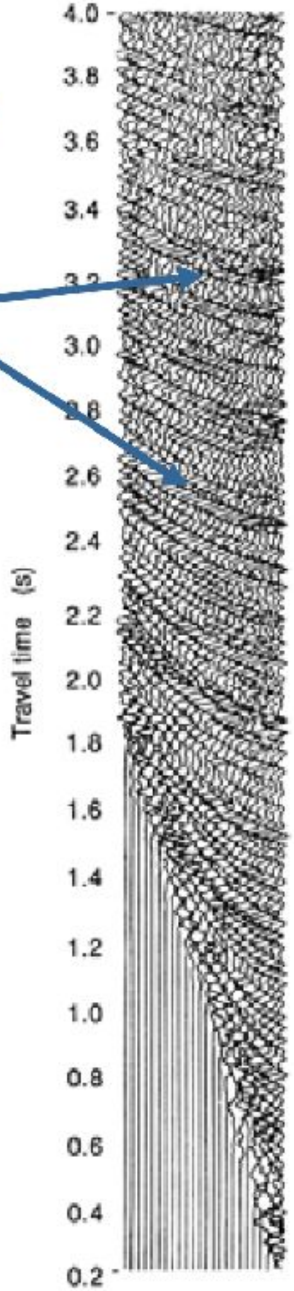
$$T_x^2 = T_0^2 + \frac{x^2}{V_1}$$

We want to subtract the NMO correction from the common depth point gather

$$\Delta T_{NMO} \approx \frac{x^2}{2T_0V_1^2}$$

**But for that we need velocity...**

reflection hyperbolae become fatter with depth (i.e. velocity)



# Годограф отраженной волны для слоистой среды.

Когда расстановка приборов короткая то годограф отраженной волны все еще является гиперболой.

$$T^2 = T_{0,n}^2 + \frac{x^2}{\overline{V}_{rms,n}^2}$$

where

$$T_{0,n} = \sum_{k=1}^{n} T_{0,k} = \sum_{k=1}^{n} \frac{2h_k}{V_k}$$

$$\overline{V}_{rms,n}^2 = \frac{\sum_{k=1}^{n} V_k^2 T_k}{\sum_{k=1}^{n} T_k}$$

Determine velocity structure one layer at a time

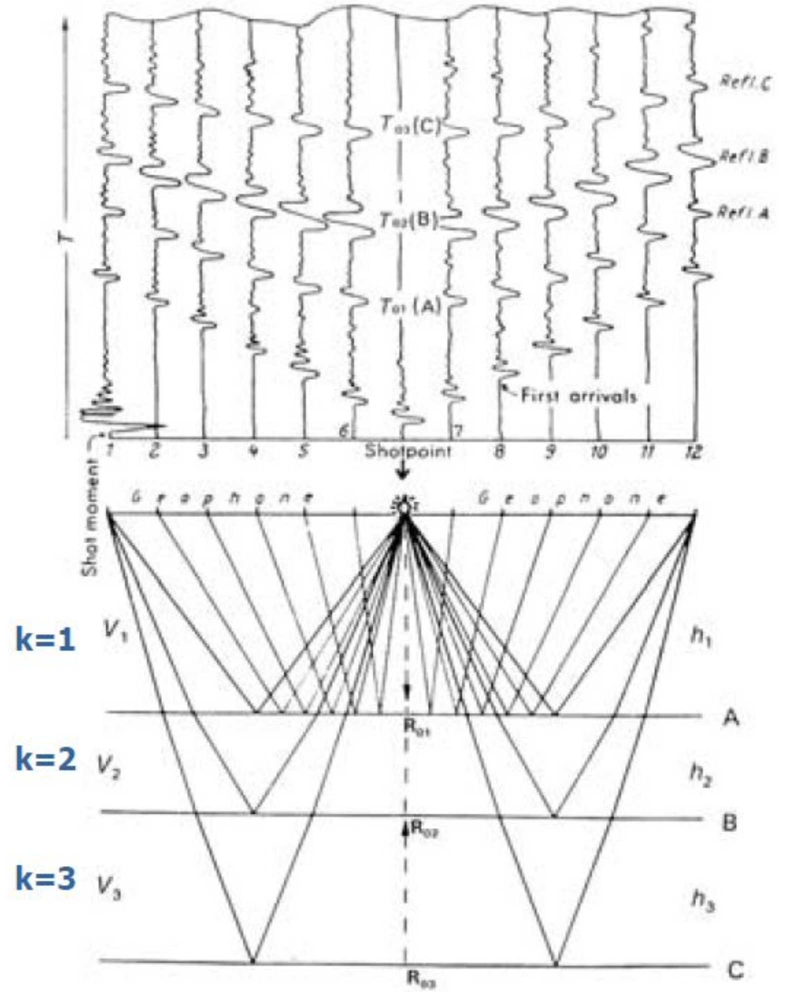



Fig. 4.14 Schematic diagram showing the production of a reflection seismogram. The 12-trace record shows the time sequence of the reflected pulses from reflecting horizons, A, B, and C. $T_{01}$, $T_{02}$, and $T_{03}$ are the two-way vertical travel-times from points $R_{01}$, $R_{02}$, and $R_{03}$, respectively, below the shotpoint. The significance of first arrivals is discussed in Section 4.4.5.

### Collecting
# Common midpoint gathers

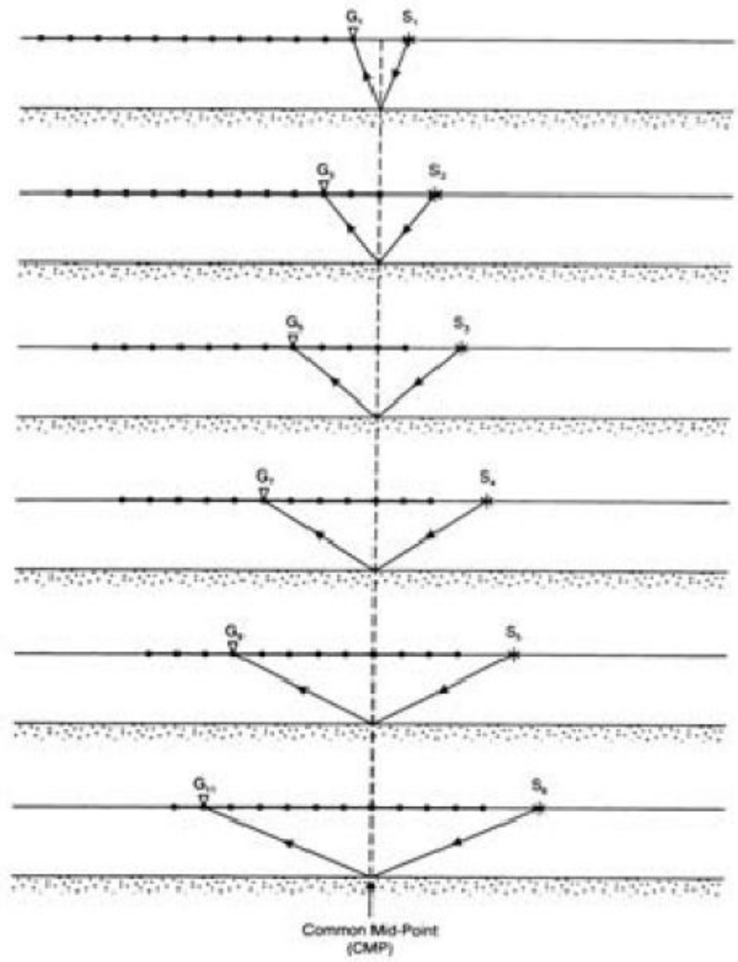
Sequentially move shot and receiver string across the surface

**Fold**

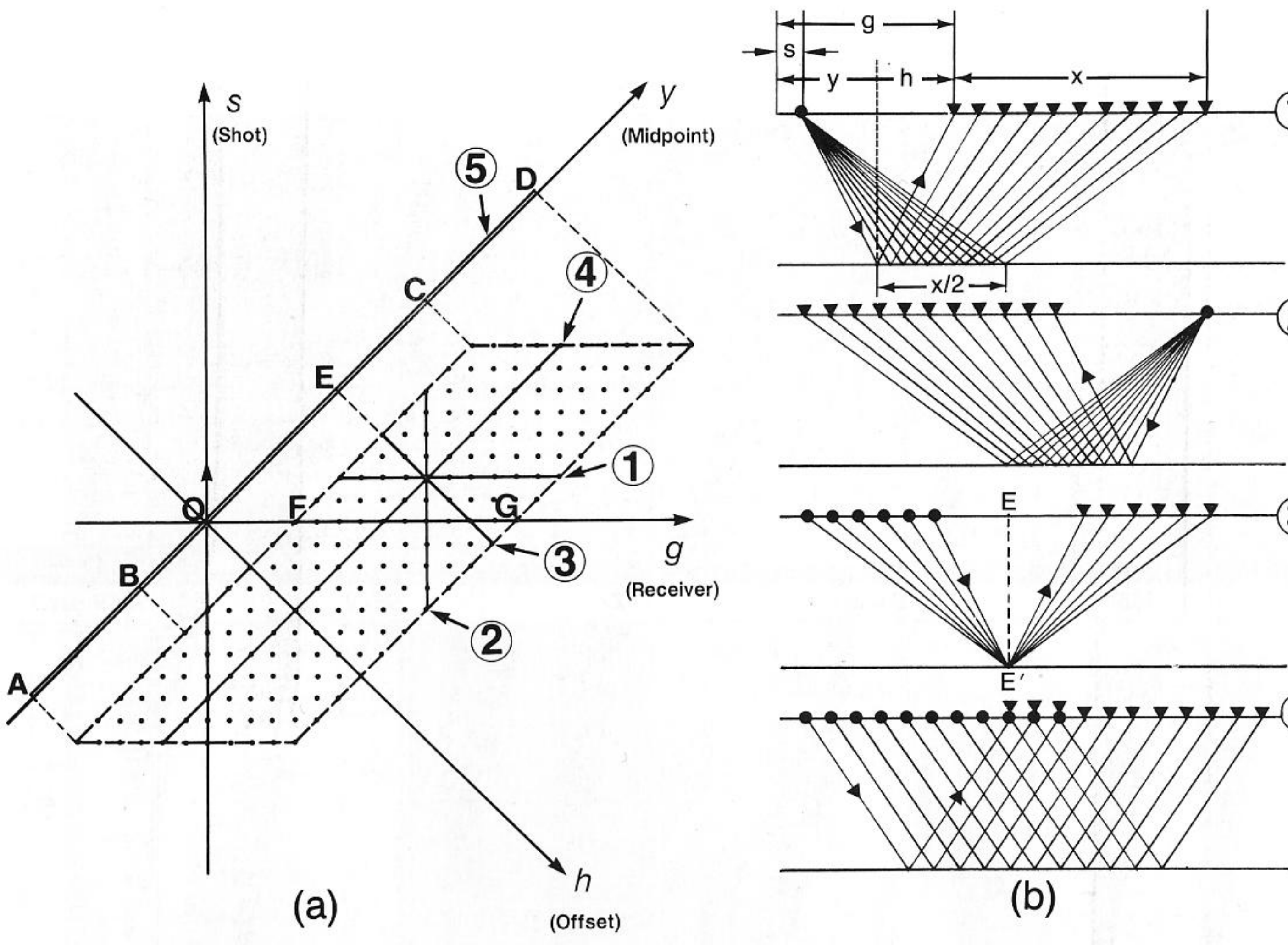
- The number of times the same point on a reflector is sampled
- In this case: 6 fold (though 12 geophones)

**Typical values**

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

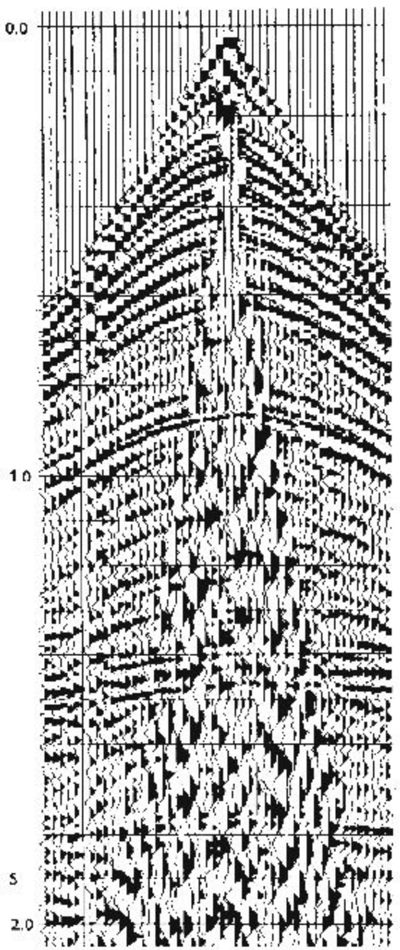


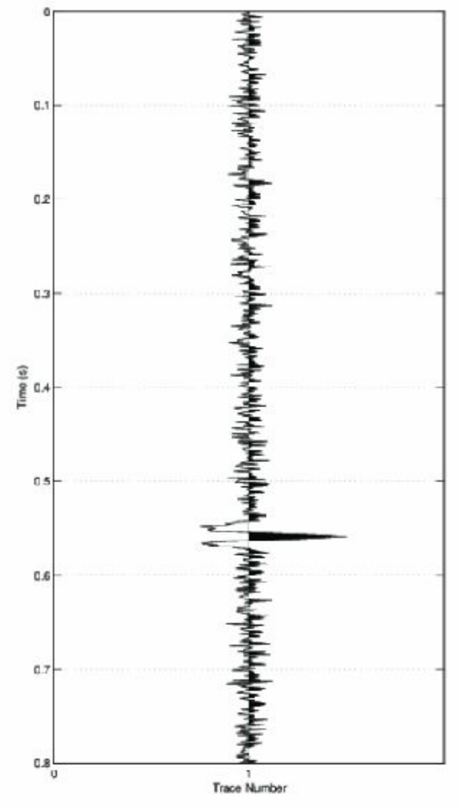
# Обобщенное изображение системы наблюдений



# Выборка ОСТ

## Stacking



# Кинематические поправки.

The reflection traveltime equation predicts a hyperbolic shape to reflections in a CMP gather. The hyperbolae become fatter/flatter with increasing velocity

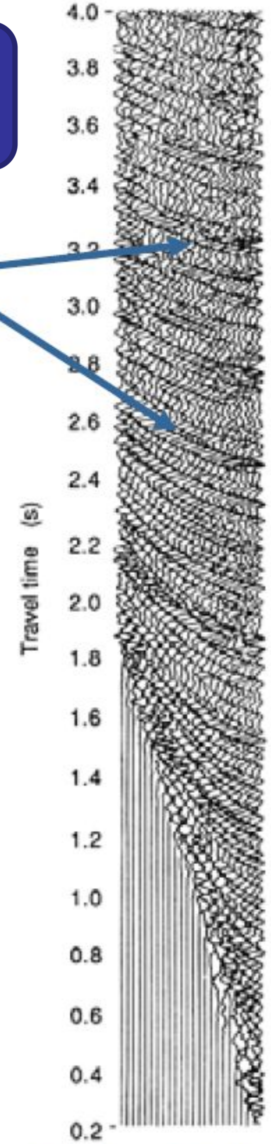
$$T_x^2 = T_0^2 + \frac{x^2}{V_1}$$

We want to subtract the NMO correction from the common depth point gather

$$\Delta T_{NMO} \approx \frac{x^2}{2T_0V_1^2}$$

**But for that we need velocity…**

reflection hyperbolae become fatter with depth (i.e. velocity)



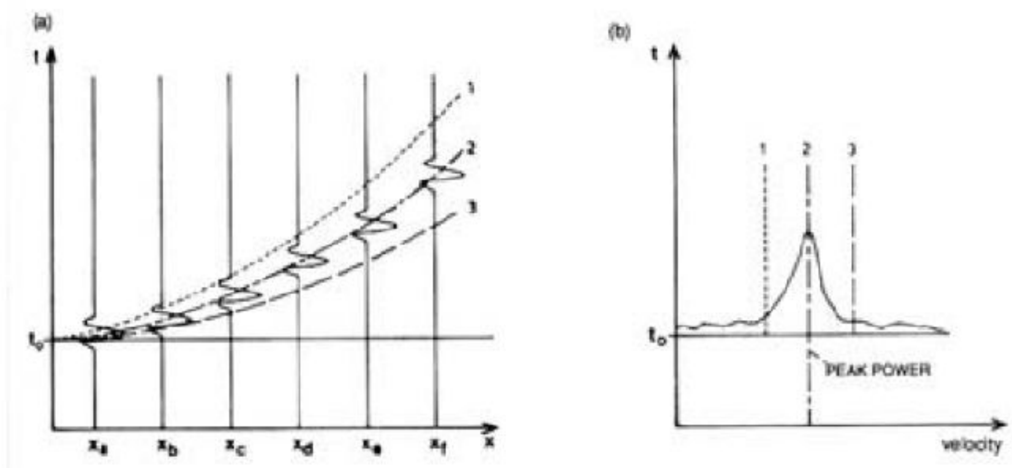
# Stacking velocity

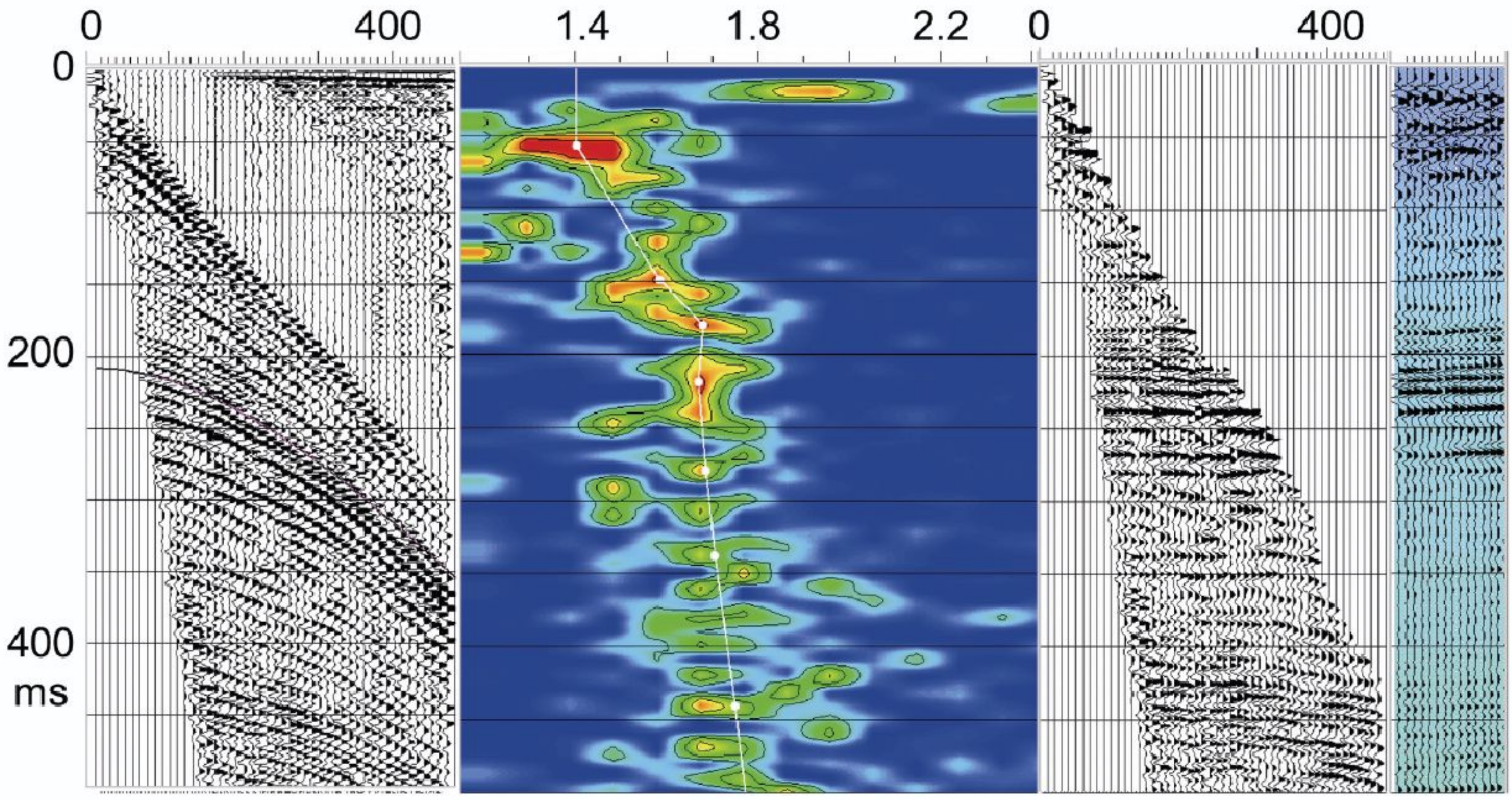
In order to stack the waveforms we need to know the velocity. We find the velocity by trial and error:

$$\Delta T_{NMO} = \frac{x^2}{2T_0V_1^2}$$

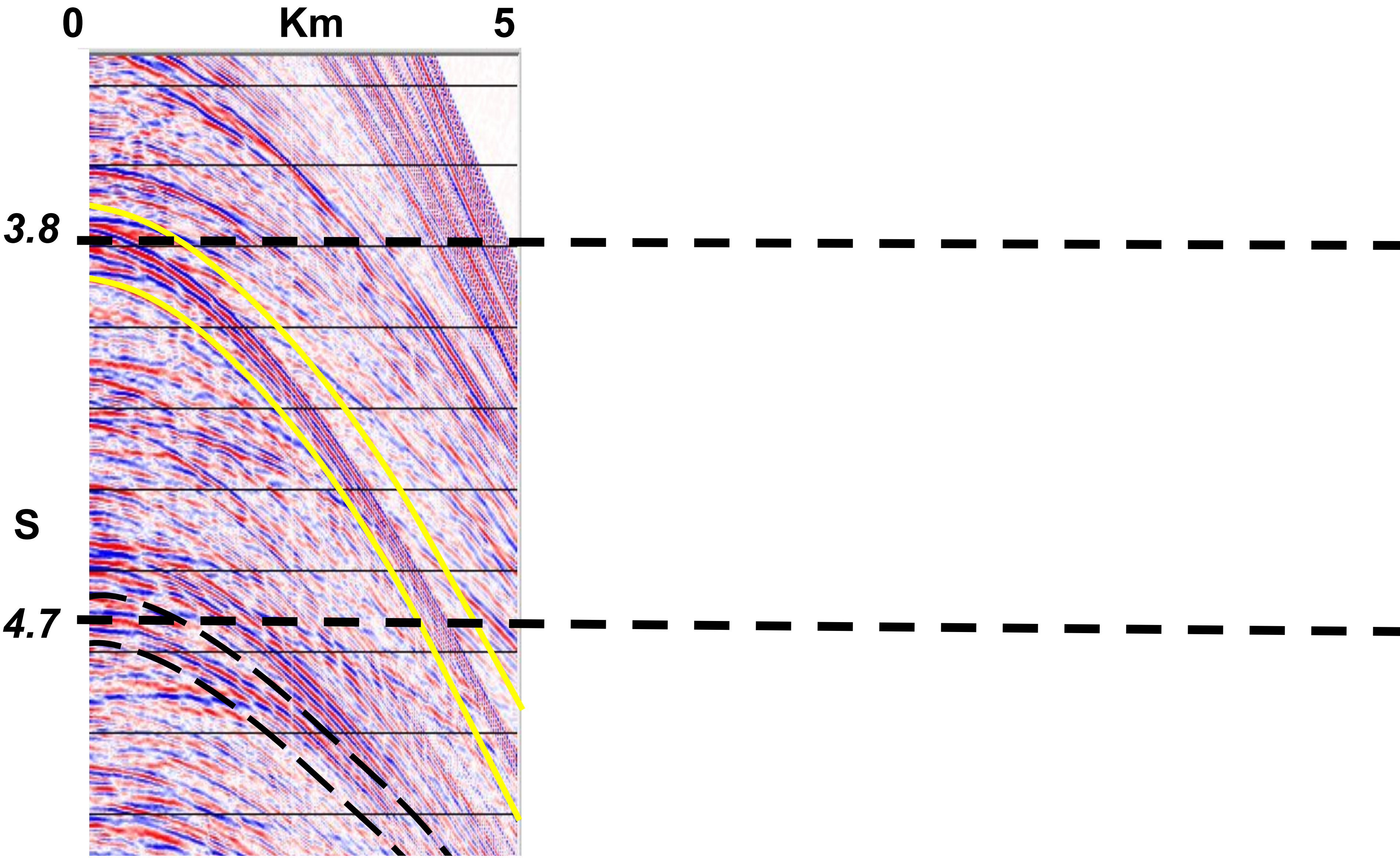
- For each velocity we calculate the hyperbolae and stack the waveforms
- The correct velocity will stack the reflections on top of one another
- So, we choose the velocity which produces the most power in the stack

$V_2$ causes the waveforms to stack on top of one another



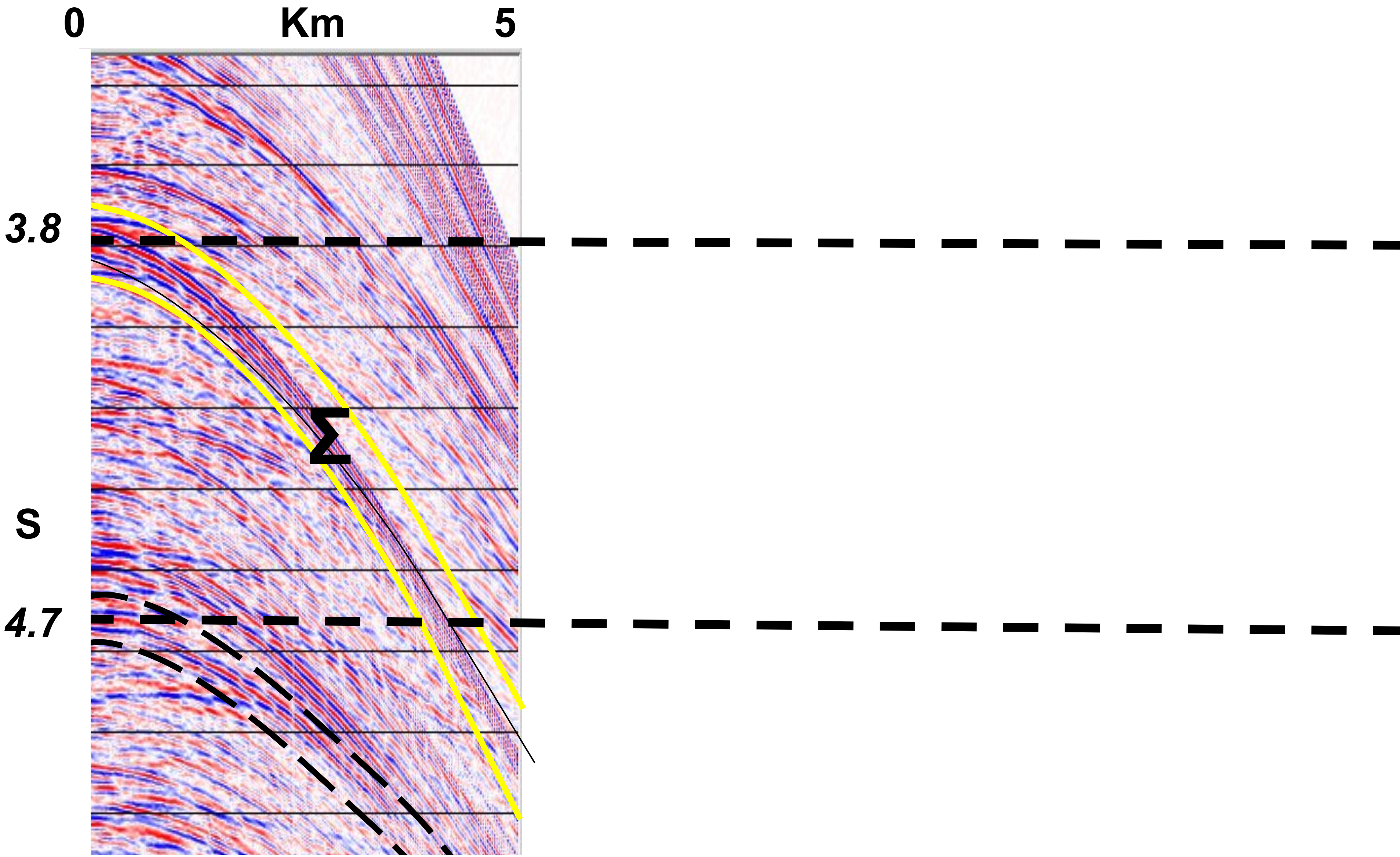

0
400
1.4
1.8
2.2
0
400
0
200
400
ms

# Conventional velocity analysis…..



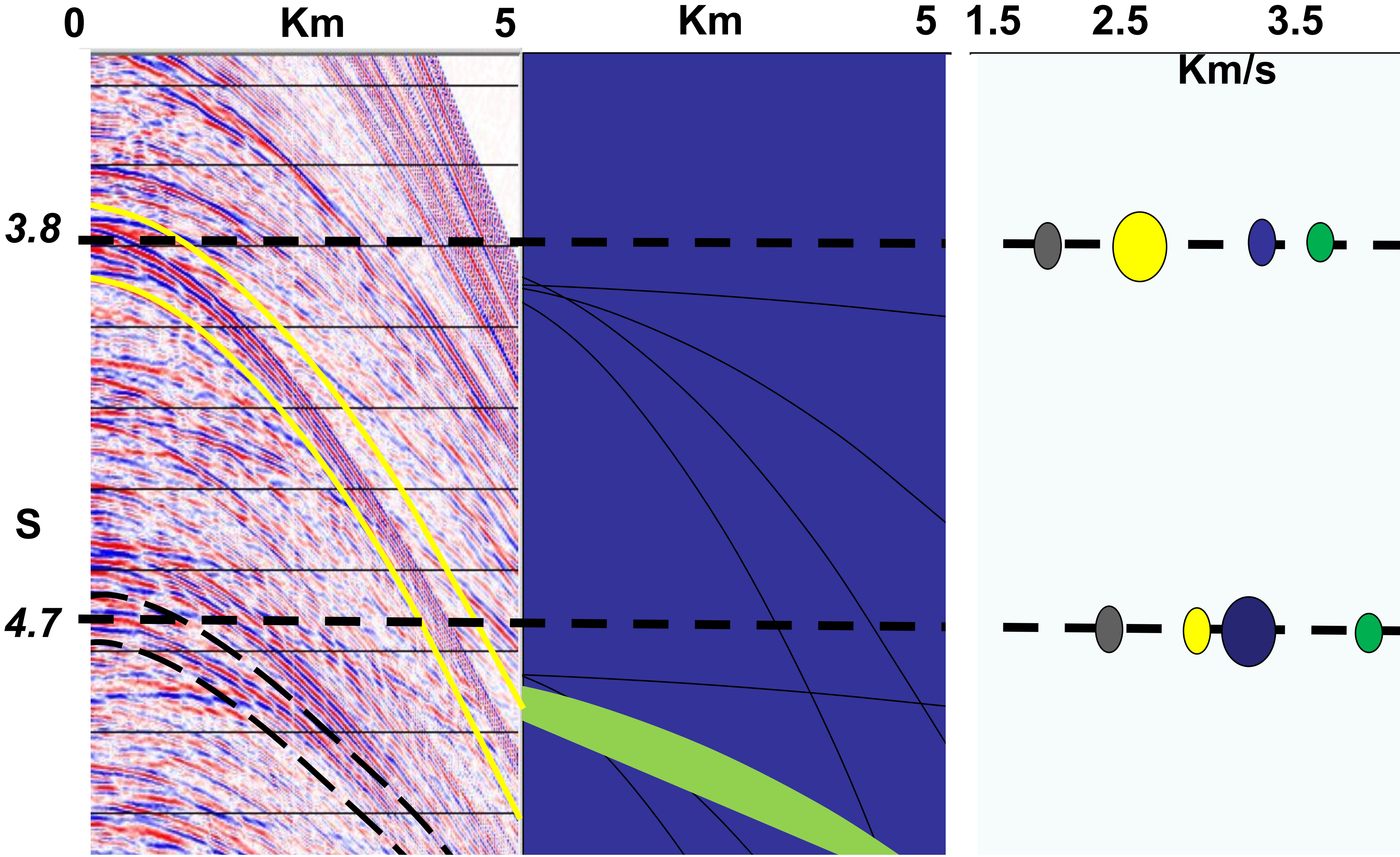

Input CMP data

# Conventional velocity analysis…..



Input CMP data

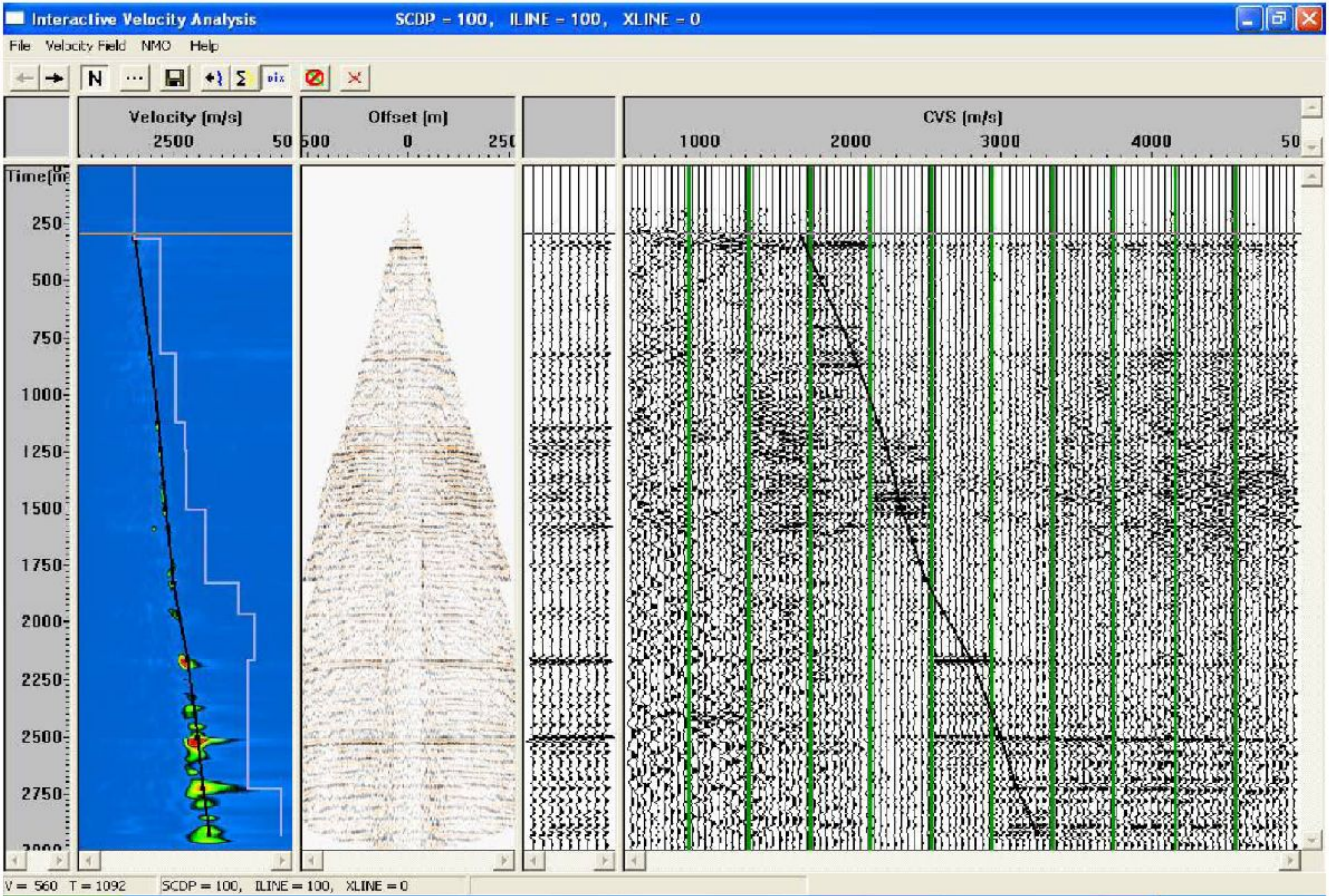
# Conventional velocity analysis…..

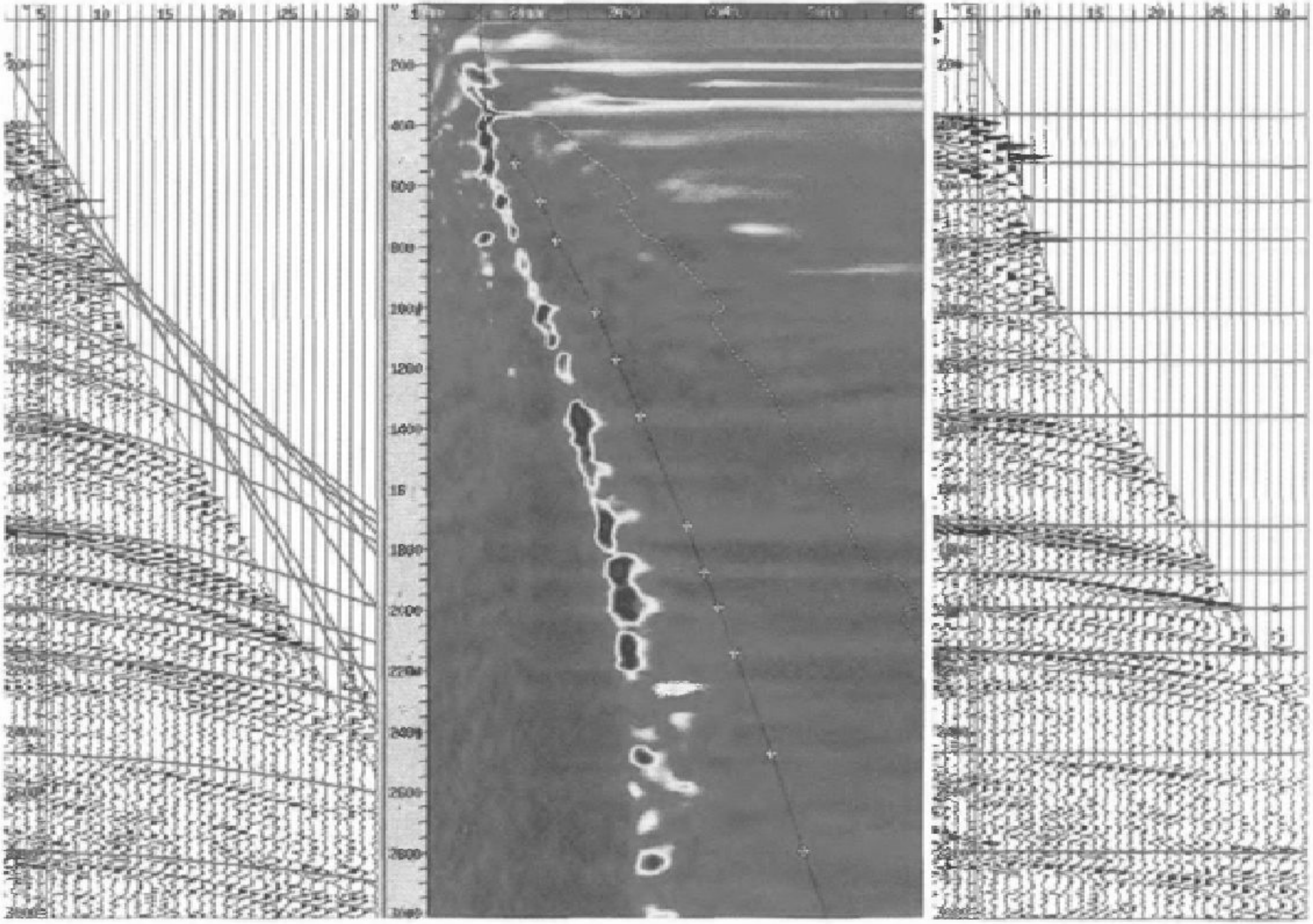


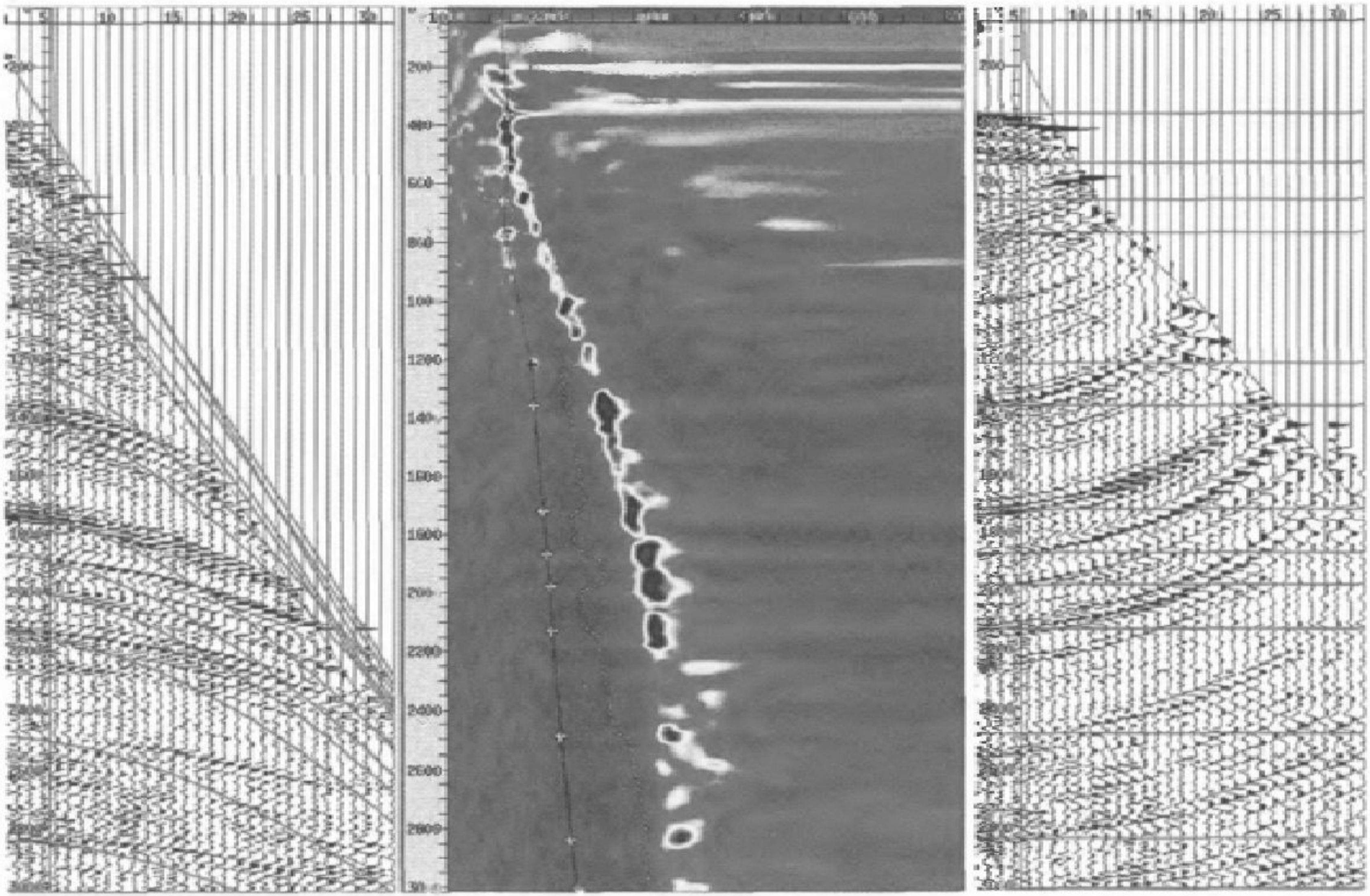

Input CMP data

scan along trajectories

pick corresponding velocity


Interactive Velocity Analysis
SCDP = 100, ILINE = 100, XLINE = 0
File Velocity Field NMO Help
Velocity (m/s)
2500
Offset (m)
0
CVS (m/s)
1000
2000
3000
4000
Time(ms)
250
500
750
1000
1250
1500
1750
2000
2250
2500
2750
V = 560 T = 1092
SCDP = 100, ILINE = 100, XLINE = 0



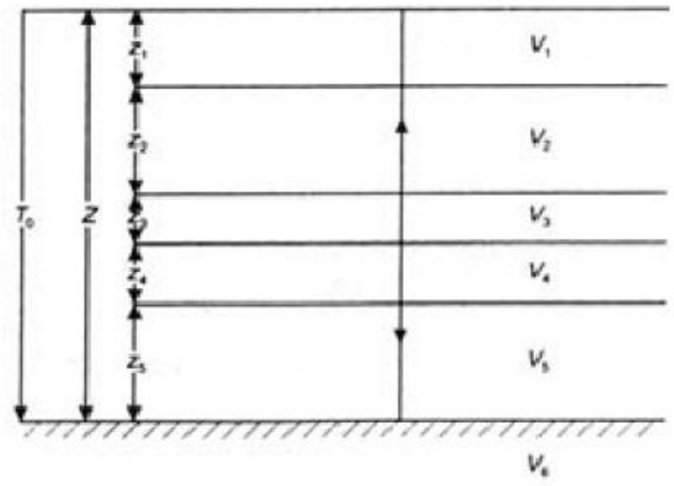


# Multiple layers

Interval velocity $V_i = {}^{z_i}\!/\!_{t_i}$

Average velocity $V' = {}^{Z}\!/\!_{T_0}$

Root-mean-square velocity $V_{RMS} = \sqrt{\frac{\sum V_i^2 t_i}{\sum t_i}}$




Two-way traveltime of ray reflected off the n$^{th}$ interface at a depth z

$$t_n = \frac{\sqrt{x^2 + 4z^2}}{V_{RMS}}$$

The interval velocity of layer n determined from the rms velocities and the two-way traveltimes to the n$^{th}$ and n-1$^{th}$ reflectors

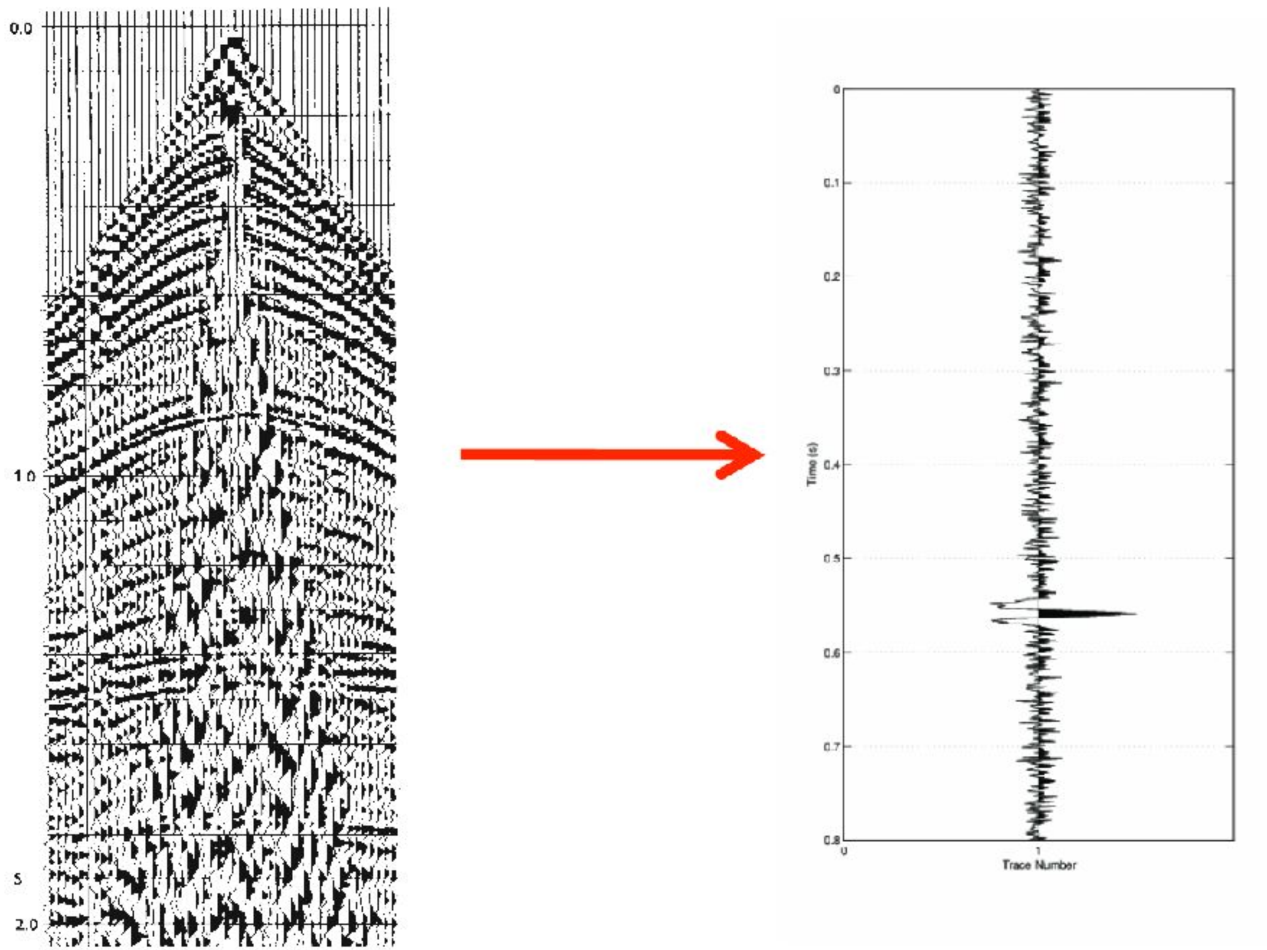
$$V_{int} = \sqrt{\frac{(V_{RMS,n})^2 t_n - (V_{RMS,n-1})^2 t_{n-1}}{t_n - t_{n-1}}}$$

**Dix equation**

The **interval velocity** can be determined from the rms velocities layer by layer starting at the top

# Выборка ОСТ

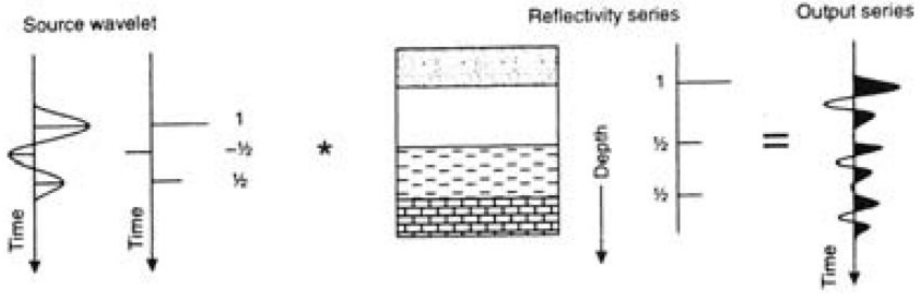
## Stacking



# Импульсная характеристика среды, свертка.

Сейсмический волны чувствительны к скачкам импеданса, которые могут быть представлены в виде импульсной характеристики среды(R).

(A)




W – сигнал от источника, тогда сейсмограмма S записанная на поверхности может быть представлена как:

**S = W * R**

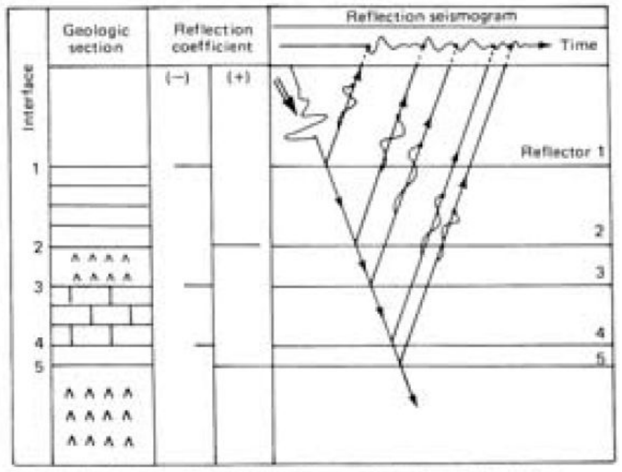



Fig. 4.18 Schematic of a model geological section, a reflectivity log, and a synthetic seismogram. The last is produced by convolving the input wavelet with the reflection effects at each interface derived from the reflectivity log. (Modified from Al-Sadi, 1982.)

# Статические поправки.

**Correct for surface topography and the weathered surface layer**

**Surface topography**

Time correction to each trace:

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

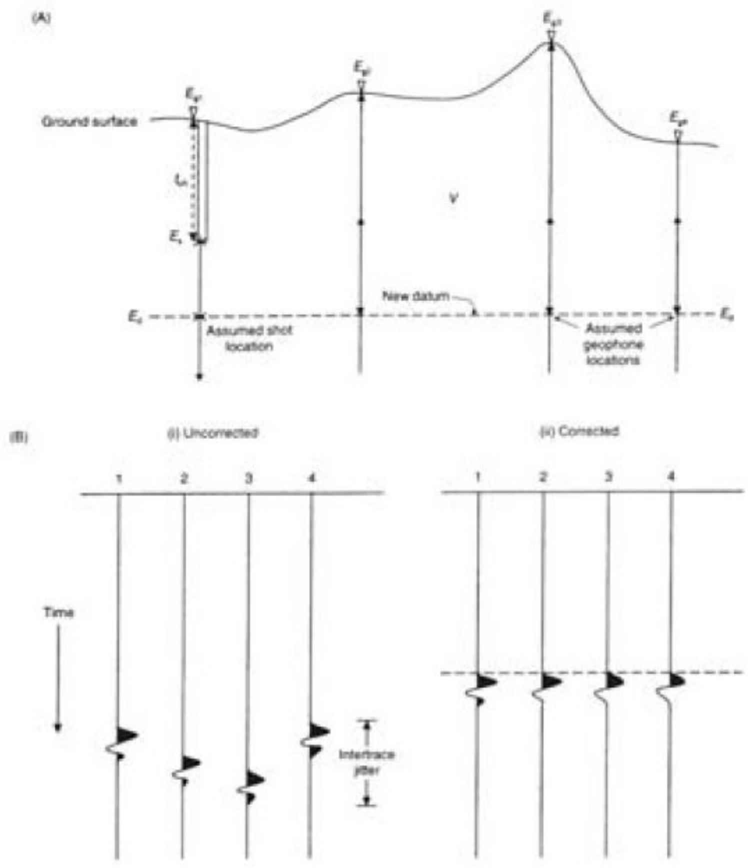
**Source depth**

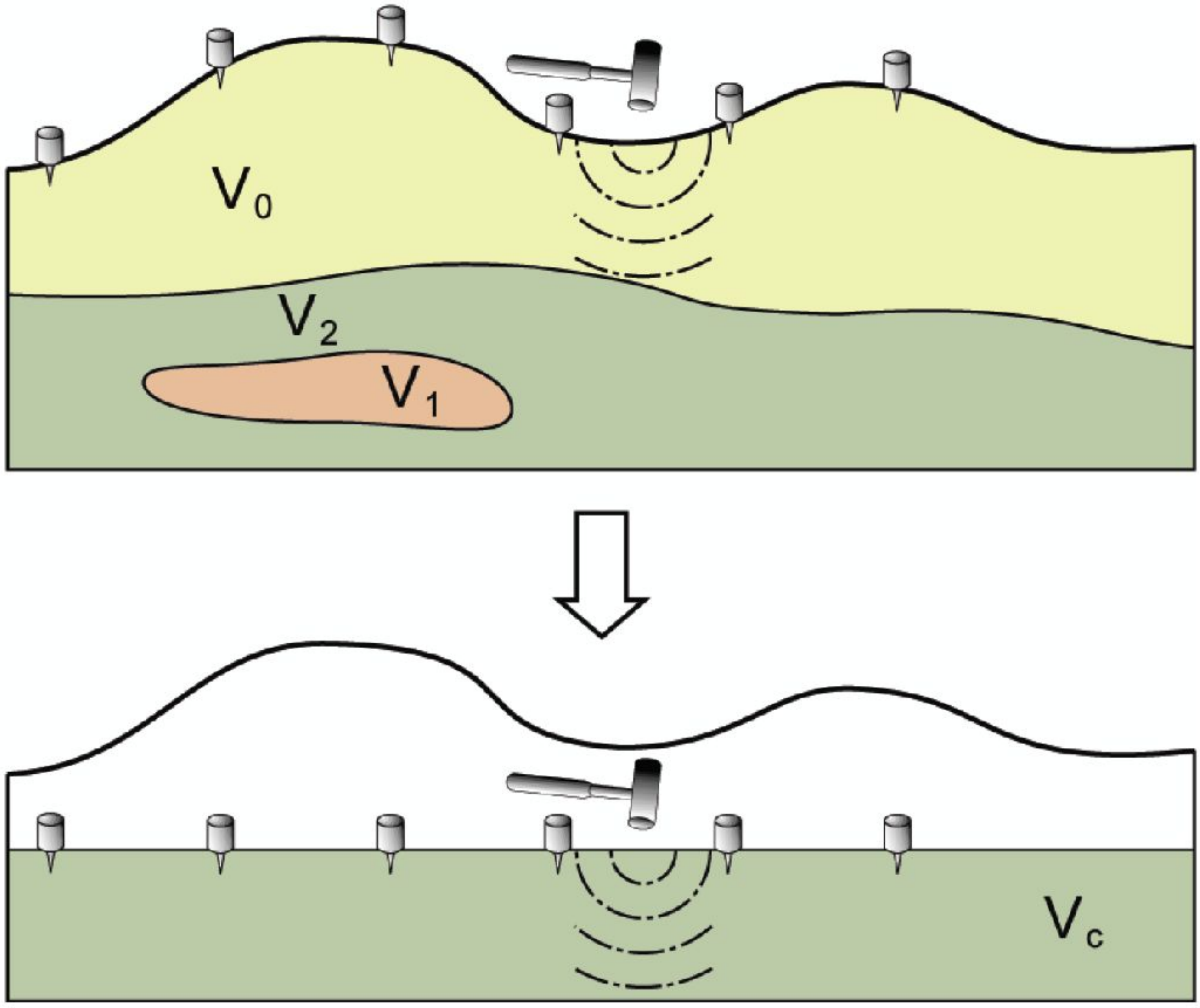
$$t_s = (E_s - E_d)/V$$

total correction

$$t_e = t_s + t_g$$

**Shift each trace by this amount to line up deeper reflectors**





V0
V2
V1
Vc

# Статические поправки.

**An example**

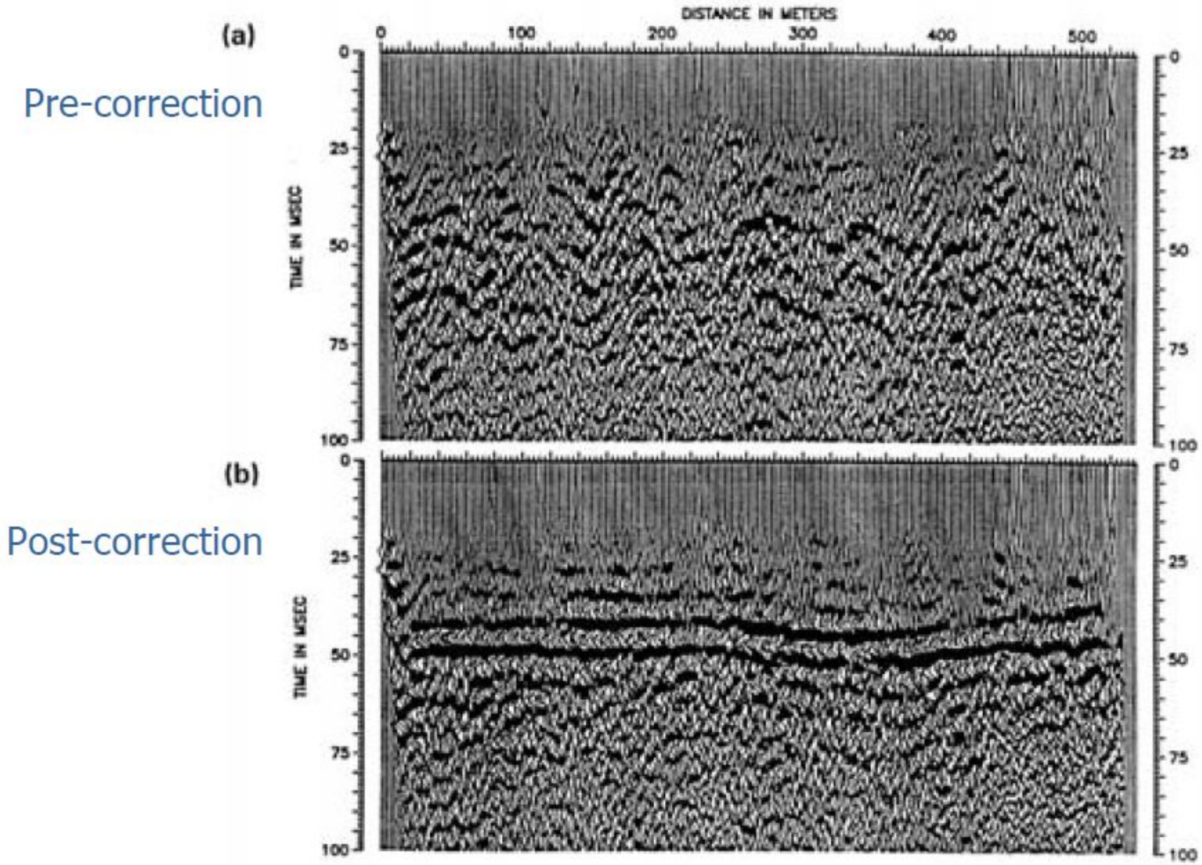



Fig. 4.17 Effect of applying residual static corrections on CDP reflection data recorded at a waste-dump site in Zealand, Denmark. Time section (a) before application of statics and (b) after application of statics. (After Ploug, 1991.)

# Fresnel Zone

**Tells us about the horizontal resolution on the surface of a reflector**

**First Fresnel Zone**

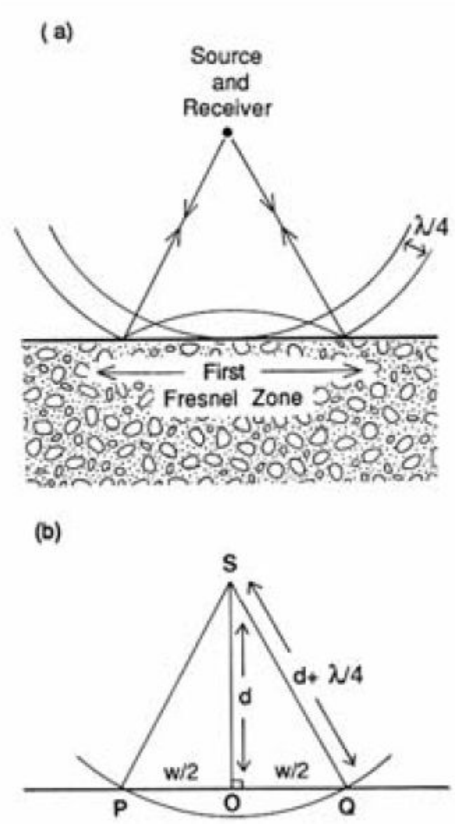
The area of a reflector that returns energy to the receiver within half a cycle of the first reflection

The width of the first Fresnel zone, w:

$$\left(d+\frac{\lambda}{4}\right)^2 = d^2 + \left(\frac{w}{2}\right)^2$$

$$w^2 = 2d\lambda + \frac{\lambda^2}{4}$$

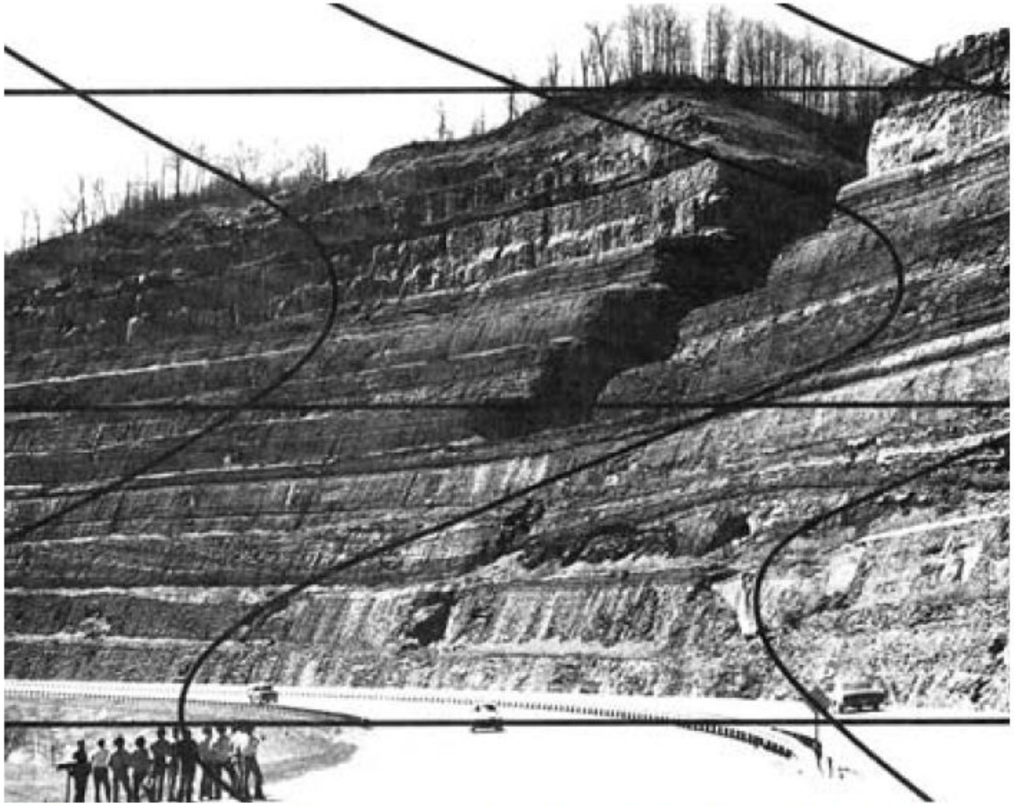
If an interface is smaller than the first Fresnel zone it appears as an point diffractor, if it is larger it appears as an interface



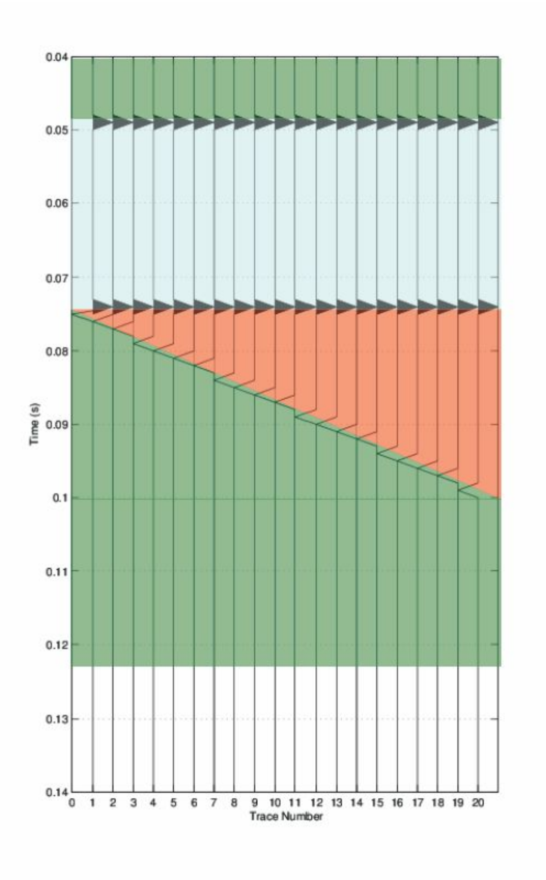

**Example**:

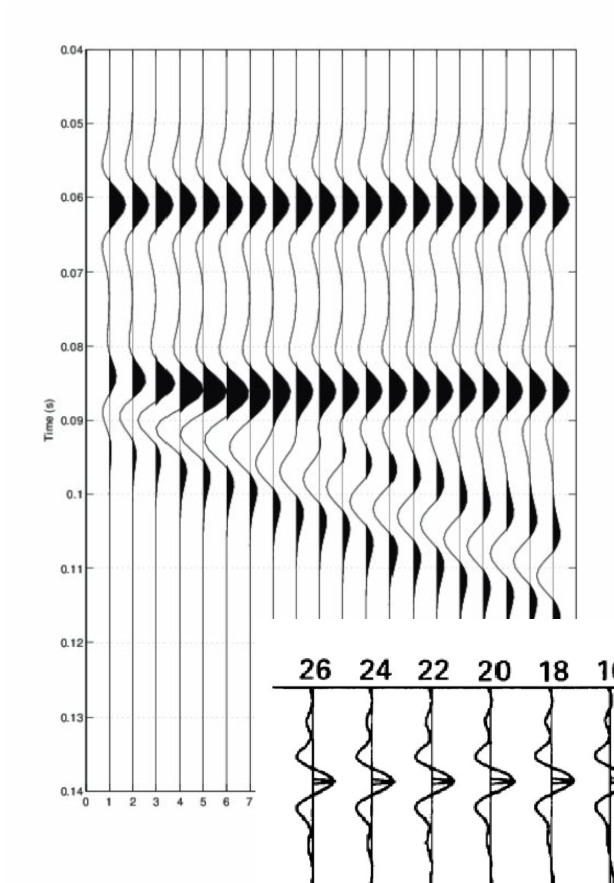
30 Hz signal, 2 km depth where $\alpha$ = 3 km/s then $\lambda$ = 0.1 km and the width of the first Fresnel zone is 0.63 km

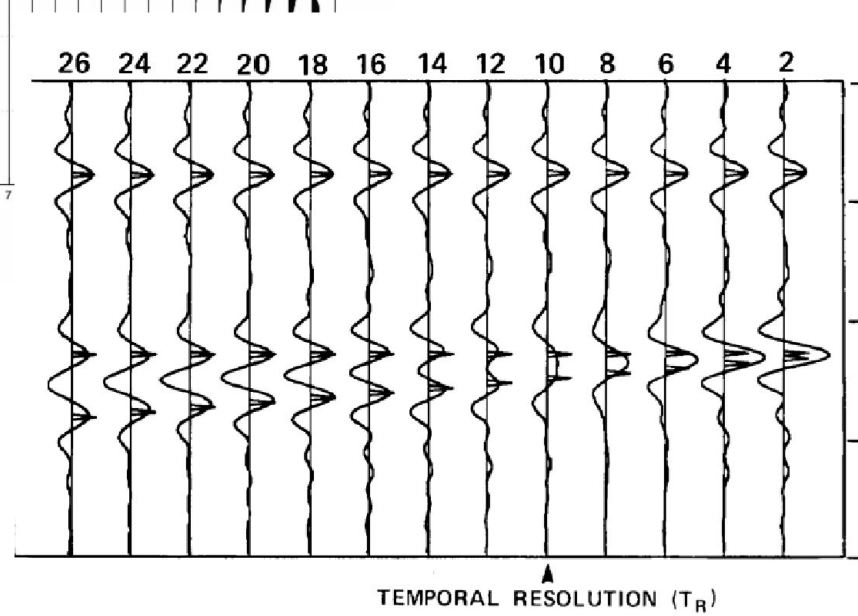
# Resolution of structure



When you have been mapping faults in the field what were the vertical offsets?

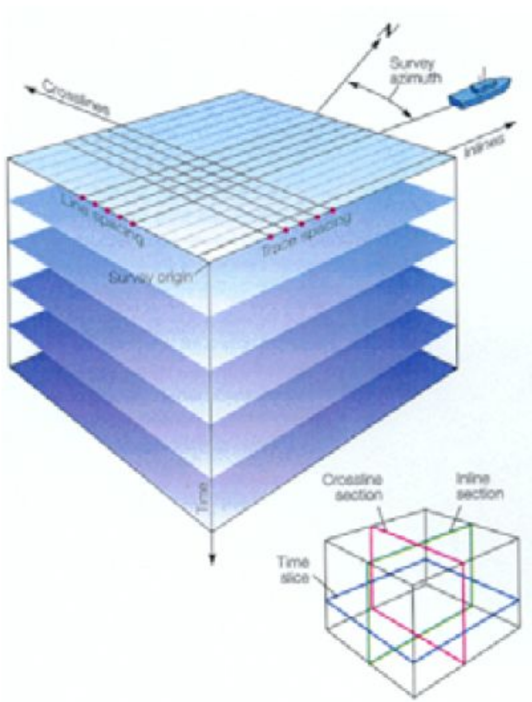

Time (s)
Trace Number

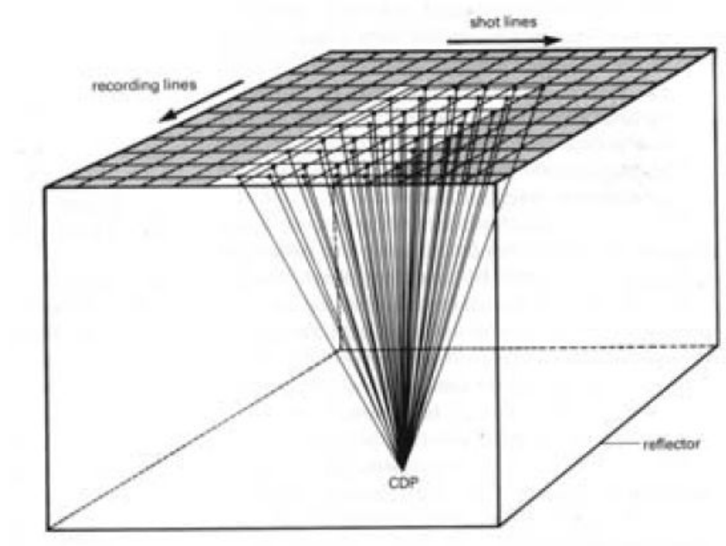

Time (s)


26 24 22 20 18 16 14 12 10 8 6 4 2
TEMPORAL RESOLUTION ($T_R$)

# 3D surveys

**Collect data on a grid rather than along a line**




Produces a data cube rather than a line