14. Velocity analysis and NMO-Correction

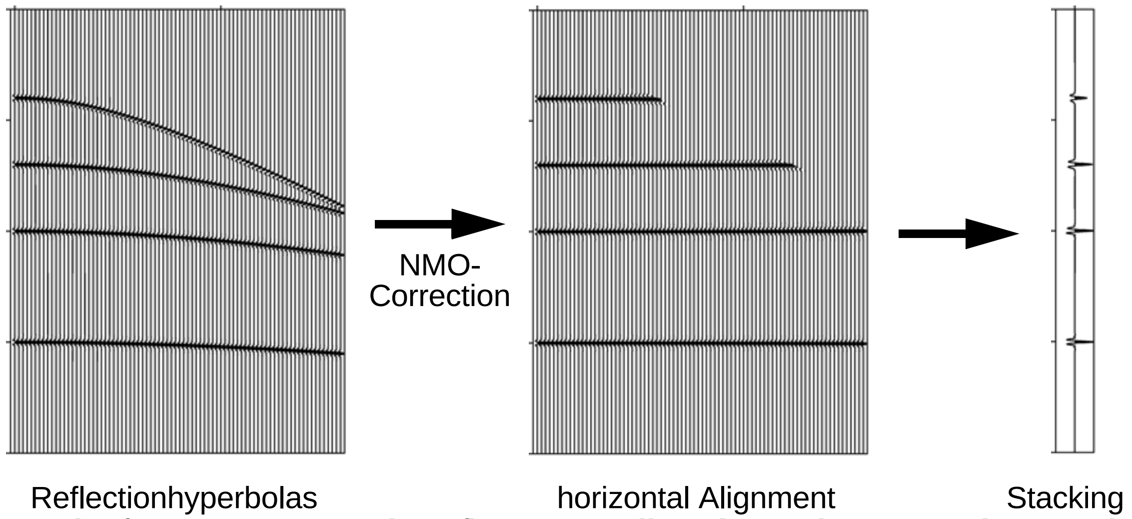
Until now we have only discussed data processing methods that improve the signal of each separate trace. We will now sum different traces, also called stacked, to improve the signal-to-noise ratio and to decrease the amount of data which will be processed to obtain an image of the subsurface. Before the stacking, a certain correction is applied on the different traces by carrying out a velocity analysis.

A good velocity model is the basis for :

- Stacking (Improvement of S/N-Ratio)
- Appropriate conversion from traveltime into depth
- Geometrical Correction (Migration)

14.1 Normal-Moveout (NMO) Correction

Principle:



Principle of NMO-Correction. The Reflections are alligned using the correct velocity, such that the events are horizontally. Then all the separate traces are stacked (summed).

The traveltime curve of the reflections for different offset between source and receiver is calculated using:

$$t^2 = t_0^2 + \frac{x^2}{v_{stack}^2}$$

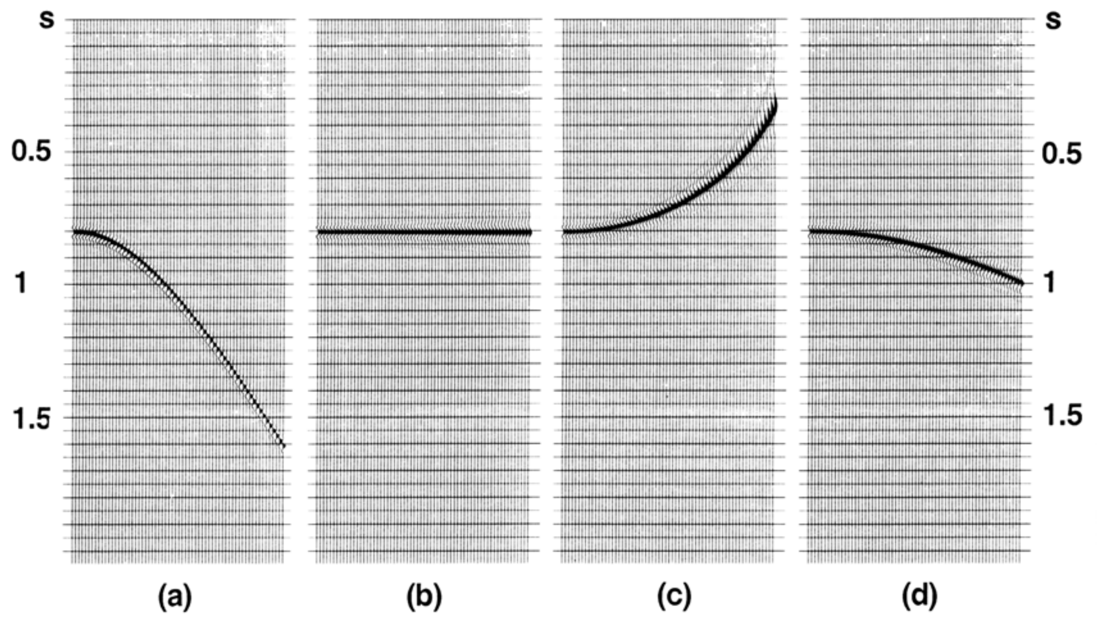
From this formula the NMO-correction can be derived and is given by:

$$\Delta t = t_0 - t(x) \qquad \text{with} \qquad t(x) = \sqrt{t_0^2 + \frac{x^2}{v_{stack}^2}}$$

The Moveout Δt is the difference in traveltime for a receiver at a distance x from the source and the traveltime t_0 for **zero-offset** distance.

The NMO-Correction depends on the offset and the velocity. In contrast to the static correction, the correction along the trace can differ. The NMO-correction is also called a **dynamic correction**.

To obtain a flattening of the reflections, the velocity must have the correct value. When the velocity is too low, the reflection is **overcorrected**; the reflection curves upwards. When the velocity is too high, the reflection is **undercorrected**; the reflection curve curves downwards.



NMO-Correction of a Reflection. (a) Reflection is not corrected; (b) with proper Velocity; (c) Velocity is too low; (d) Velocity is too high.

Remark:
Low velocities have a stronger curvature then high velocities.

14.2 Methods for Velocity analysis.

The aim of the velocity analysis is to find the velocity, that flattens a reflection hyperbola, which returns the best result when stacking is applied. This velocity is not always the real RMS velocity. Therefore, a distinction is made between:

- v_{stack}: the velocity that returns the best stacking result.
- v_{rms}: the actual RMS-velocity of a layer.

For a horizontal layer and small offsets, both velocities are similar. When the reflectors are dipping then v_{stack} is not equal to the actual velocity, but equal to the velocity that results in a similar reflection hyperbola.

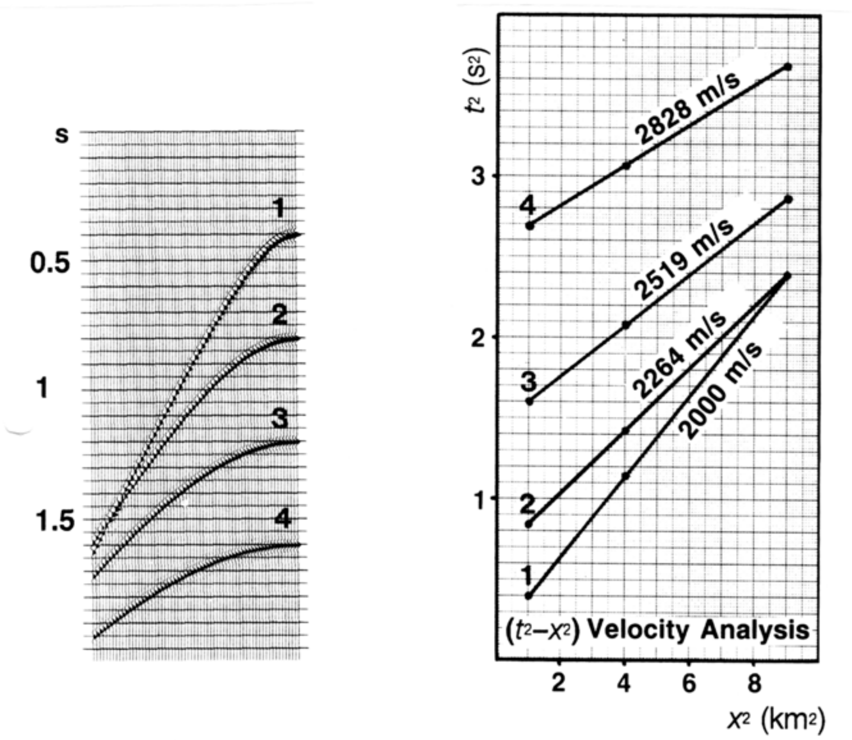
There are different ways to determine the velocity:

- (t^2-x^2)-Analysis.
- Constant velocity panels (CVP).
- Constant velocity stacks (CVS).
- Analysis of velocity spectra.

For all methods, selected CMP gathers are used.

(t^2-x^2)-Analysis

The (t^2-x^2)-Analysis is based on the fact, that the Moveout-expression for the square of t and x result in a linear event. When different values for x and t are plotted, the slope can be used to determine v^2, the square root returns the proper velocity.



Example of a t^2-x^2-Analysis.

CVP - "Constant velocity panels"

The NMO-correction is applied for a CMP using different constant velocities. The results of the different velocities are compared and the velocity that results in a flattening of the hyperbolas is the velocity for a certain reflector. .

CVS - "Constant velocity stacks"

Similar to the CVP-method the data is NMO-corrected. This is carried out for several CMP gathers and the NMO-corrected data is stacked and displayed as a panel for each different stacking velocity. Stacking velocities are picked directly from the constant velocity stack panel by choosing the velocity that yields the best stack response at a selected event.
CVP and CVS both have the disadvantage that the velocity is approximated as good as the distance between two test velocities. Both methods can be used for quality control and for analysis of noisy data.

Velocity-Spectrum

The velocity spectrum is obtained when the stacking results for a range of velocities are plotted in a panel for each velocity side by side on a plane of velocity versus two-way travel-time. This can be plotted as traces or as iso-amplitudes. This method is commonly used by interactive software to determine the velocities.

Different possible methods can be used to determine a velocity spectrum:

- amplitude of stacking
- normalised amplitude of stacking
- Semblance
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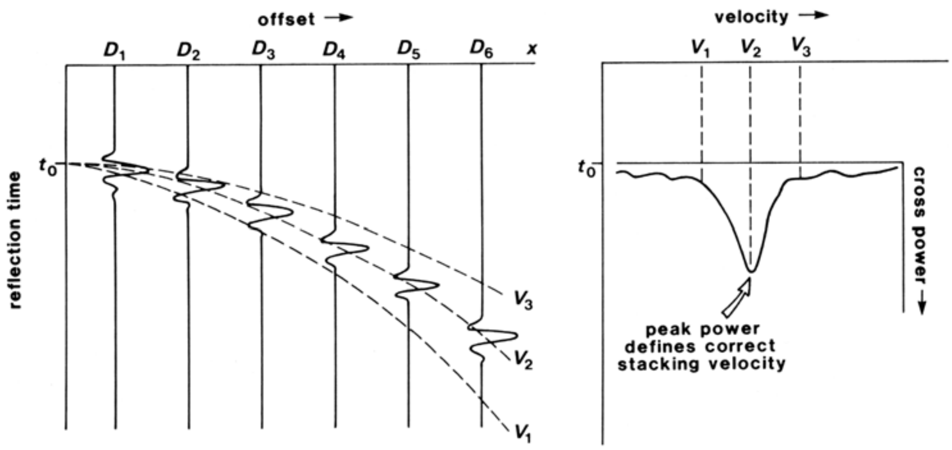


Amplitude of Stacking

$$s_t = \sum_{i=1}^{n} w_{i,t}$$

where n=number of NMO corrected traces in the CMP gather; w=amplitude value on the i-th trace at twoway time t.

Normalised Amplitude of stacking

$$ns_t = \frac{|s_t|}{\sum_{i=1}^{n} |w_{i,t}|}$$

Semblance

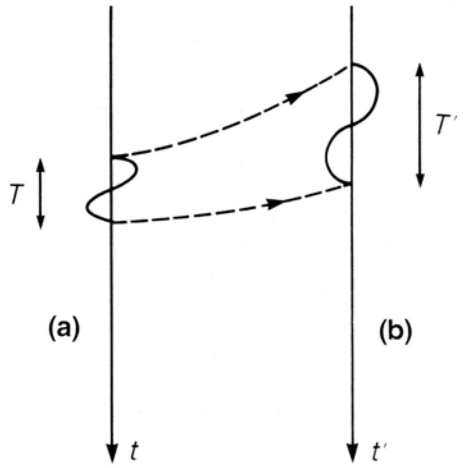
$$\text{Semblance} = \frac{1}{n} \cdot \frac{\sum_t s_t^2}{\sum_t \sum_i w_{i,t}^2}$$

Semblance-Calculations are only used for velocity analysis, because it returns always a value between 0 and 1.

14.3 Problem of “Stretching” of the data caused by NMO correction

NMO is a dynamic correction, that means that the values of a single trace are shifted with different amounts. This results for larger offets in a stretching of the data and an artificial increase of the wavelength occurs.

This effect is relatively large for horizontal reflections with low velocities. To reduce the effect of the stretching on the result of the stacking procedure, the part with severe stretching of the data is muted from the data (“stretch-mute”).



Dynamic correction results in a stretching of the data, which results in a artificial increase of the wavelength.

14.4 Factors influencing velocity estimates

The accuracy of the velocity analysis is influenced by different factors:

- Depth of the Reflectors
- Moveout of the Reflection
- Spread length
- Bandwidth of the data
- S/N-Ratio
- Static Corrections
- Dip of the Reflector
- Number of traces

By a combination of CMP’s that lie close together (Super gather), the accuracy is increased when a small number of traces per CMP are available (low coverage).
Errors due to dipping layers and unsufficient static corrections can be reduced (DMO and Reststatics, are discussed later on).