Seismic Waves and Noise

- **Signal**
  - Primary reflections
    - generated by waves that have been reflected once from an interface
    - the most important part of the seismic section

- **Noise**
  1. direct waves
     - travel directly from source to receiver
     - usually first arrivals on the section
     - T-X curve is a straight line with intercept=0
  2. head waves (refractions)
     - critically refracted waves
     - T-X curve is a straight line with intercept≠0
The fold of the stack is determined by the number of traces in the CMP gather. The formula for calculating the fold is:

\[
\text{Fold} = \frac{N_{\text{rec}} \times \Delta X_{\text{rec}}}{2 \times \Delta X_{\text{src}}} 
\]

Fold Coverage = 6
Normal Move-Out (NMO)

Reflection 1 boundary

Normal Move-Out: 1 reflector

\[ T = \frac{R}{v} = \frac{(4H^2 + x^2)^{1/2}}{v} \]

- \( x \) = source-receiver distance
- \( R \) = total distance travelled by ray
- \( H \) = thickness of layer
- \( v \) = wave speed

We do not know distance, but we know time:

\[ T = T_0 \left( 1 + \frac{x^2}{v^2 T_0^2} \right)^{1/2} \]

where \( T_0 \) is zero-offset (\( x=0 \)) traveltime: \( T_0 = \frac{2H}{v} \)
Normal Move-Out (NMO)
Normal Move-Out (NMO)

Single horizontal layer
- \( T^2 = T_0^2 + X^2/V^2 \)
- It is a hyperbola with apex at \( X= 0 \) and \( T_0 = 2H/V \)
  - \( V \) and \( H \) are the layer velocity and thickness
- \( T^2 - X^2 \) plot is a straight line whose slope= \( 1/V^2 \) and intercept = \( T_0^2 \)
- \( T^2 - X^2 \) plot can be used to find \( V \) and \( H \)
- Normal moveout (NMO)
  - the difference between travel times at offsets \( X \) and 0
  - \( \Delta T_{\text{NMO}} (X) \approx X^2/(2T_0V^2) \)
  - used to flatten the T-X curve before stacking
- We usually know \( T, T_0, \) and \( X \) from the seismic section and we want to know \( V \) and \( H \).
Normal Moveout Correction

The fold of the stack is determined by the number of traces in the CMP gather.

\[ t_x^2 = t_0^2 + \frac{x^2}{v_i^2} \]

- NMO \( V = 2000 \text{ m/s} \) event **undercorrected**
- NMO \( V = 1700 \text{ m/s} \) good stack response
- NMO \( V = 1500 \text{ m/s} \) event **overcorrected**
  poor stack response
**Multiple Layers - Which Velocity?**

\[ v_{\text{rms}} = \sqrt{\frac{v_1^2 t_1 + v_2^2 t_2 + \ldots}{t_1 + t_2 + \ldots}} \]

- \( V_{\text{int}} \) - constant velocity of a single layer (which can be very thin).
- \( V_{\text{nmo}} \) - velocity required to best NMO correct the data using the hyperbolic NMO assumption. The difference between \( V_{\text{nmo}} \) and \( V_{\text{stack}} \) is subtle.
- \( V_{\text{rms}} \) - for multiple flat layers and assuming the offset is small compared with the depth, a hyperbolic moveout equation can be derived as a truncated power series in which \( V_{\text{rms}} \) is used as velocity. The root-mean-square (RMS) velocity is calculated from interval velocities as shown in the figure. At large offsets (greater than around 3km) more accurate NMO corrections can be performed by retaining the next term of the equation.
- \( V_{\text{stack}} \) - is the velocity required to best stack the data using the best-fit hyperbola over the available offset range.