Fundamentals of Seismic Reflection Surveys

Emad A. Al-Heety
Department of Applied Geology
University of Anbar
Email: emadsalah@uoanbar.edu.iq
Normal move out (NMO)

- Normal move out refers to the later arrival times of rays reflected of a horizontal interface for receivers offset from the shot point or source.
- Normal move out only applies to horizontal reflectors.
- The later arrival times for reflected rays of any generic interface is called move out.
- Move out patterns vary for reflectors of different geometry.
Normal move out (NMO)

- Importance of NMO
- Having determined the layer velocity, we can use the predicted quadratic shape to identify reflectors.
- Then correct (shift traces) and stack to enhance signal to noise.
\[ \Delta_{NMO} = T_x - T_0 \approx \frac{X^2}{2T_0 V_1^2} \]
Normal move out (NMO)

- Reflection from a single horizontal impedance contrast:

Arrival time

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

or

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

The arrival time curve is a hyperbola

Note: a geophone spread GG' samples RR' of the reflector. RR' = GG'/2.
Arrival time curve is quadratic

\[ T_x^2 = T_0^2 + x^2/V_1^2 \]

So, if plot \( T_2 \) vs. \( x_2 \) we can determine the \( V_1 \) and \( h_1 \) from the slope and intercept.
Normal move out (NMO)

- Multiple layers
  Use Snell’s Law to trace ray paths

At each interface

\[
\frac{\sin ip}{V_{p1}} = \frac{\sin rp}{V_{p2}} = P
\]
In order to select the seismic energy source, we consider the following:

1. Energy input
2. Repeatability
3. Cost
4. Convenience
Types of seismic sources

I. Rifles and guns
   - Cheap
   - Repeatable – fire into water filled hole
   - Shallow targets 0–50m

II. Sledge hammer
   - Cheap
   - Repeatable once plate is stable (and with training!)
   - Targets 15–50m
Rifle

Sledge hammer
Types of seismic sources

III. Weight drops

- Cheap
- Repeatable – automated
- Targets > 50m
Types of seismic sources

IV. Vibroseis

- No pulse, frequency sweep
- Significant signal with stacking/deconvolution
Types of seismic sources

V. Explosives
- Various sizes – target depth
- Safety and expense can be an issue.

VI. Air guns
- At sea
- Very repeatable
- Large array for big signals
Seismic receivers

- **Geophone**
  - Cylindrical coil suspended in a magnetic field
  - The inertia of the coil causes motion relative to the magnet generating an electrical signal.
  - Geophones are sensitive to velocity
Seismic receivers

- Hydrophones
  - Used at sea
  - Use piezoelectric minerals to sense pressure variations.
Seismic receivers

- **Instrument response**
  - The relation between the input ground motion and the output electrical signal.
- **Natural Frequency**
  - The frequency which produces the maximum amplitude output.
Seismic receivers

- **Damping**
  - Reduces the amplitude of the natural frequency response and prevents infinite oscillations
  - Want a flat response
Deployment

- Important considerations
  - Need good coupling to the ground – spike
  - Mini-arrays to reduce surface wave noise
- Offset of geophones
  - Small offsets
  - Near-vertical incidence retains P-energy
  - High resolution of subsurface reflectors
  → Seismic reflection analysis
Deployment

- Large offsets
  - Improves velocity sensitivity
  - Provides horizontal averages only
    → Seismic refraction analysis
- Types of geophones spread
  It means the relative position of the shot point to the geophone. The following figure shows the different geophones spread:
1- Split Spread: (SP) is placed at the center of spread.

\[ G_1 \ G_2 \ G_3 \ G_4 \ G_5 \ G_6 \ \text{SP} \ G_7 \ G_8 \ G_9 \ G_{10} \ G_{11} \ G_{12} \]

2- Split Spread with a gap: (SP) is placed at the center of spread with plotting a gap.

\[ G_1 \ G_2 \ G_3 \ G_4 \ G_5 \ G_6 \ \text{SP} \ G_7 \ G_8 \ G_9 \ G_{10} \ G_{11} \ G_{12} \]

3- End of Spread: (SP) is placed at the end of spread.

\[ \text{SP} \ G_1 \ G_2 \ G_3 \ G_4 \ G_5 \ G_6 \ G_7 \ G_8 \ G_9 \ G_{10} \ G_{11} \ G_{12} \]