Seismic methods:
Seismic reflection - IV

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

Seismic reflection processing
Flow overview

These are the main steps in processing
The order in which they are applied is variable
Dipping layers

For horizontal reflectors the reflection point is vertically below the source/receiver.

For dipping layers the reflection comes from a point up dip.

Therefore, a traveltime section will always show a reduced dip.

\[ \tan \delta' = \sin \delta \]

Migration

The process of trying to move reflections back to their point of origin.

Intended to deal with:
- Dipping interfaces
- Curved interfaces
- Diffractions
- Reflections from the 3rd dimension

Time migration: restore the geometrical relationships between seismic events on the time section.

Depth migration: generates a true depth section. Necessary when strong lateral velocity gradients.
**Diffraction hyperbolae**

A to B: normal incidence reflections
B to C: diffractions from P

→ **Huygens’ principle**

Equation of the diffraction hyperbolae:

\[
I = \frac{2}{\alpha_1} \sqrt{z_1^2 + x^2}
\]

Note that a diffraction hyperbolae has a greater curvature than a reflection hyperbolae

Recall the equation for a reflection hyperbolae:

\[
I = \frac{2}{\alpha_1} \sqrt{z_1^2 + \left(\frac{x}{2}\right)^2}
\]

**A non-migrated section**
Anticlines and synclines

Anticlines broaden
Synclines produce a bow-tie

Pre-migration stack

Applied Geophysics – Seismic reflection IV
Anticlines and synclines

Migration procedure

For a zero offset seismic section (i.e., stacked data):

Diffraction hyperbolae are identified by scanning adjacent traces and collapsed back to the point of origin.

Kirchhoff migration uses hyperbola.
Velocity distortions

Velocity relates the time section recorded to a depth section …horizontal and vertical velocity variations distort the section

Example: vertical velocity gradient

**Velocity distortions:**

Fault distortions

* Apparent curvature of fault plane
* Thinning of beds

Figure 4.9. Ambiguities remain when using seismic data to map and interpret structural features. Since velocities are variable with depth, distortion of fault planes and bed thickness due to velocity effects is a possibility. This example shows a case where velocities increase with depth (the usual situation).

**Velocity distortions:**

Lateral velocity variations

Produce pull-ups and pull-downs
Oil and gas
Source, reservoir and trap

Examples
Salt dome
Common traps in Gulf of Mexico
**Examples**

**Faults and flat spots**

Flat spots and bright spots: indicate oil or gas

**Delineating bedrock**

Why would we want to know this?

**Correlating seismic with well log data**

- Drilling a well provides “ground truth” to a seismic interpretation
- Borehole provides velocities for depth migration
- Synthetic seismograms generated from the well log can be tied to the seismic

**Fig. 4.20 Optimum common offset (OCO) reflection sections and the borehole log from Dryden, Ontario, Canada, showing a steep-sided bedrock valley. 100 Hz geophone used with an offset of 35 m. (After Pullan and Hunner, 1990.)**
Examples

Delineating bedrock

**Over-interpretation?**
Look for additional data
- Local geology
- Other surveys
- Boreholes

![Section of CMP reflection section below the survey line at Cedar Bog, Ohio, U.S.A.](image)

**Objective:**
Map subsurface location of aquifer for the purpose of drilling a well

**Surface geology**

**LEGEND**
- **LOW PERMEABILITY SEGMENTS**
  - Colwell Mud
  - Vermont Rhyolite
- **HIGH PERMEABILITY SEGMENTS**
  - Mount Dandenong Sandstone
  - Dandenong Ranges Sandstone
- **BEDROCK**
  - Cretaceous
- **Infilt Rate Curiosity Boundary**
- **Seismic Survey Line**
- **Fault**
- **Aquitard**

![Map of Ypretna surface geology and seismic survey location near Geelong, Victoria, Australia. Borehole Bowden, head of the main source of water supply; groundwater recharge is believed to occur in the aquifer at Beregara High.](image)

Applied Geophysics – Seismic reflection IV
Examples
Groundwater

Objective:
Map subsurface location of aquifer for the purpose of drilling a well

Examples
Locating faults

- Migrating fluids
- Seismic hazard

Identified as discontinuities in reflection surfaces

None of these faults visible at the surface – suggests recent inactivity
Examples

Locating voids

Reflection survey above an abandoned mine

Voids indicated by absence of the otherwise continuous reflector

What other methods could we use?

Fig. 4.33 12-fold CDP stacked seismic section with generalized geological cross-section (top) at the site of an abandoned coal mine near Pittsburg, Kansas, U.S.A. The absence of coal is indicated by the absence of the blackened reflection horizon at approximately 25 m. Drilling, as indicated on the stacked section, confirmed the interpreted voids and intact coal. The first two cycles after the first arrivals are stacked reflection signals per meter. Two 100 Hz geophones connected in series with a 0.3 m inline spacing were used. (After Miller and Smerly, 1994)