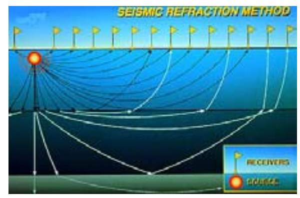
Seismic methods: Refraction III

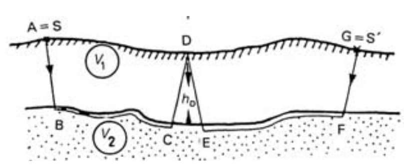
Examples and limitations



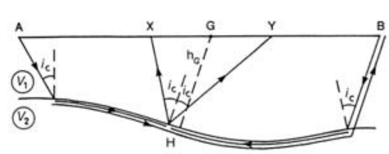
Refraction reading: Sharma p158 - 186

Generalized reciprocal method

The **plus-minus method** assumes a planar interface and shallow dip between C and E



The **generalized reciprocal approach** uses two geophones, X and Y, recording refracted arrivals originating **from the same point on the refractor** avoiding these assumptions



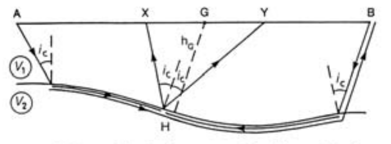
Generalized reciprocal method

Define two functions:

1. Velocity analysis function, T_V

$$T_V = \frac{T_{AY} - T_{BX} + T_{AB}}{2}$$

This is the traveltime from A to H

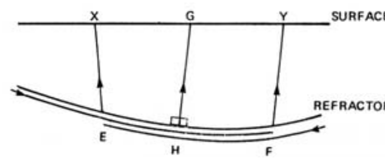


2. Time-depth function, T_G

$$T_G = \frac{T_{AY} + T_{BX} - T_{AB} - \left(XY/V'\right)}{2}$$

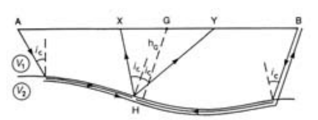
This is the traveltime along EX or FY minus the traveltime of the projection of GX or GY along the refractor interface

i.e. the traveltime along the GH

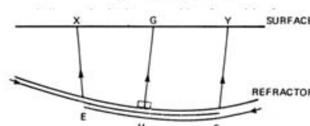


V′ is the apparent refractor velocity determined from T_V

Generalized reciprocal method

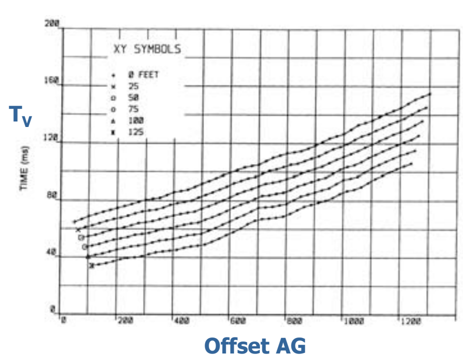


Procedure:

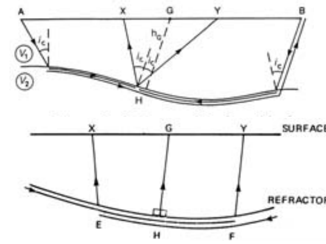


Velocity analysis function, T_V

- Calculate T_V as a function of offset AG for a variety of XY distances
- The optimal XY is when E and F converge on H
- Optimal XY is identified by the smoothest T_V curve
- Refractor velocity V′ is the reciprocal of the slope of T_V
- Can determine variations in V′ along the length of the profile



Generalized reciprocal method



Procedure:

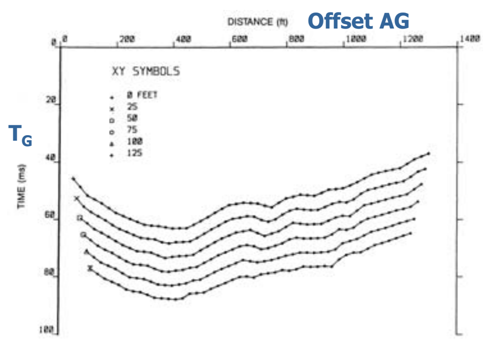
Time-depth function, T_G

- Calculate T_G as a function of offset AG for a variety of XY distances
- Optimal XY is identified by the roughest T_G curve
- Calculate average velocity from surface to refractor

$$\bar{V} = \sqrt{\frac{V'^2 \, XY}{XY + 2T_G V'}}$$

- Calculate the depth from T_G and the average velocity

$$h = \frac{T_G \bar{V} V'}{\sqrt{V'^2 - \bar{V}^2}}$$



Example

Rockhead determination

for waste disposal site

Refraction study to determine if a permit should be issued for a waste disposal site

Site description:

- Isolated site adjacent to a river.
- Basalt basement rock outcrops adjacent to site on far side from the river.
- Basal believed to underlie entire site.
- Overburden is alluvium and windblown sand

Refraction deployment:

- Sledge hammer ineffective due to high attenuation of loose surface sand. Used explosives
- Series of geophone arrays used to form one long array across the site
- For each array use one short and one long offset shot at each end plus a mid-spread shot

Example

Rockhead determination

for waste disposal site

Forward shots

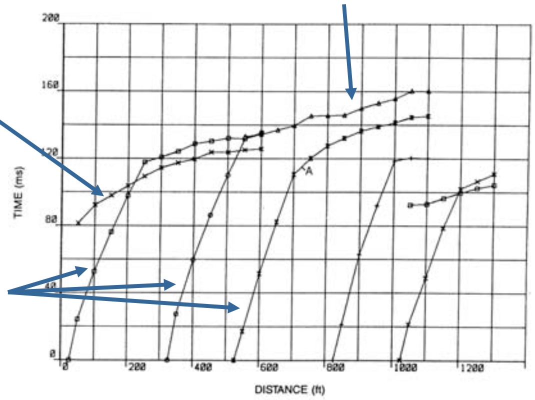
How many layers?

Near parallel arrivals tell us there is near-constant lower layer velocity

Long offset shot

- No direct arrivals as no geophones close enough
- Arrives earlier due to shallower refractor depth beneath long offset shot

Direct arrivals provide overburden velocities along profiles

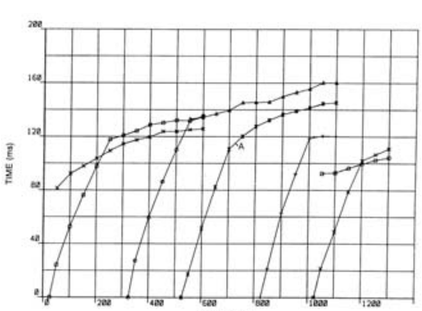


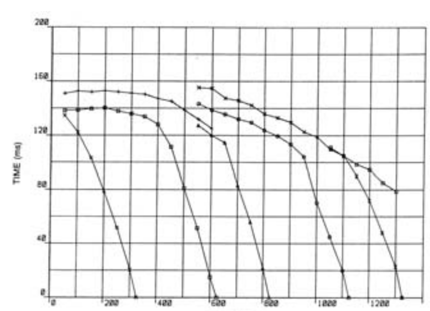
Example

Rockhead determination

for waste disposal site

Forward shots **Reversed shots**



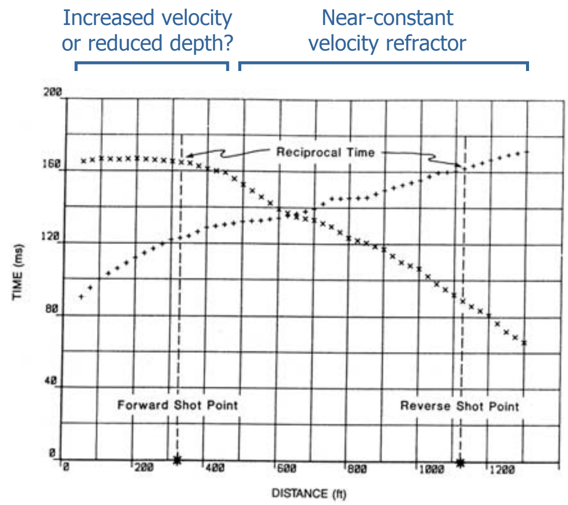


Example
Rockhead determination
for waste disposal site

Phantoming

- Used to generate a refraction arrival time much longer that it is possible to collect
- Could be used to determine intercept, or
- In preparation for reciprocal method

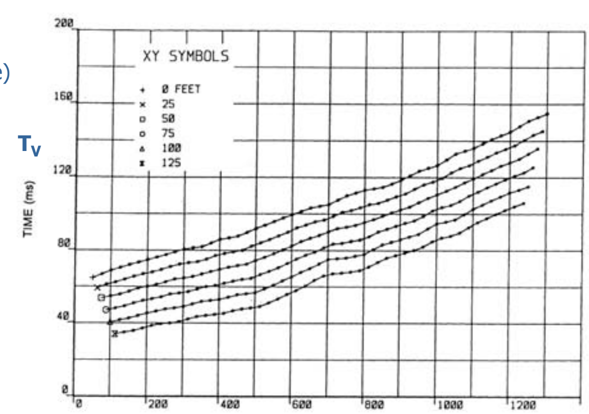
(Data also interpolated between each geophone to increase range of possible XY distances)



Example
Rockhead determination
for waste disposal site

Velocity analysis:

- T_V calculated for a range of XY values
- Optimal XY: 0 feet (The smoothest curve)



Applied Geophysics – Refraction III

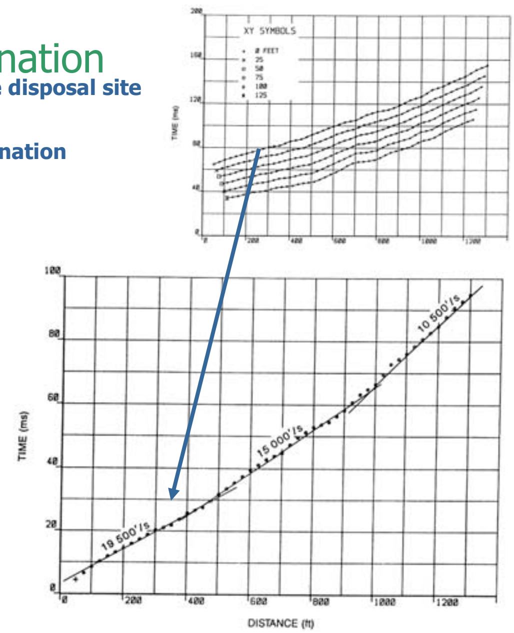
Example

Rockhead determination

for waste disposal site

Refractor velocity determination

- Velocity is 1/slope of optimal T_V plot
- Decided on three refractor velocities as data fitted well with three straight line segments



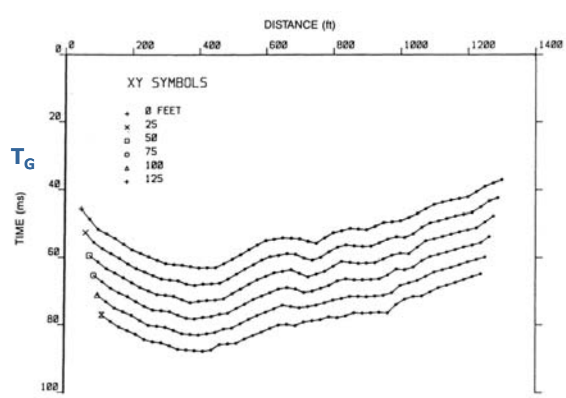
Example

Rockhead determination

for waste disposal site

Time-depth plot

- To determine depth of refractor beneath each geophone point
- Again, optimal XY is zero offset: the roughest curve on the T_G plot
- Using T_G, the refractor and overburden velocity we can calculate the depth of the refractor beneath each geophone



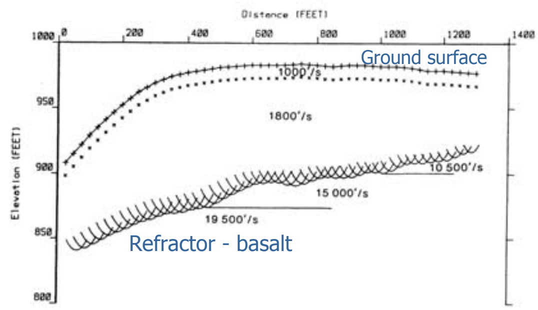
Example

Rockhead determination

for waste disposal site

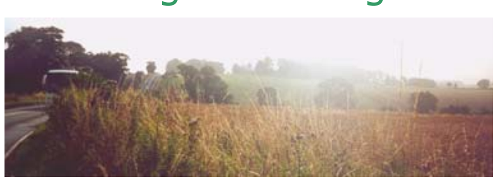
Refractor depth profile

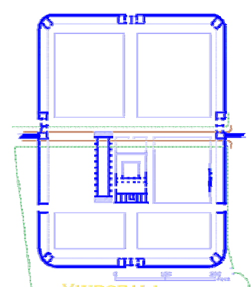
- Using T_G, the refractor and overburden velocity, we can calculate the depth of the refractor beneath each geophone
- Note it is the distance of the refractor from the geophone so draw circles
- Refractor surface is tangent to all the circles



Examples

Archeological investigations





Locating the vallum

Adjacent to Vindobala Fort on Hadrian's Wall

- Want to locate the buried vallum for possible excavation and preservation
- Vallum: a flat bottomed ditch (!)

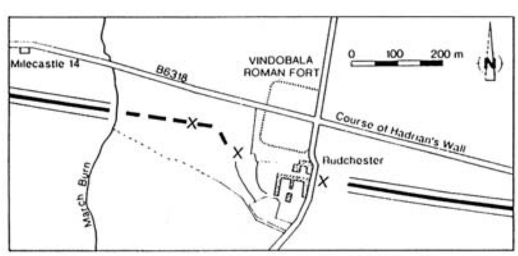


Fig. 4.52 Location map showing (solid line) the known course of the vallum from surface evidence and (dashed line) its course delineated by the previous seismic work of Goulty *et al.* (1990). Nine new seismic lines (see Fig. 4.54b) were positioned between the stretches marked by crosses immediately south of the Vindobala Fort (northern England).

Examples
Archeological investigations

P-wave refraction lines
- Sledge hammer source
- 2m geophone spacing
- 50m lines reversed

S-wave refraction lines
- Rubber maul hammer striking horizontally on a vertical plate
- 2m horizontal geophone spacing

From Sharma: "The stand was orientated perpendicular to the seismic line, so the S-waves propagating along the line were horizontally polarized in the transverse direction for being detected by transversely orientated geophones."

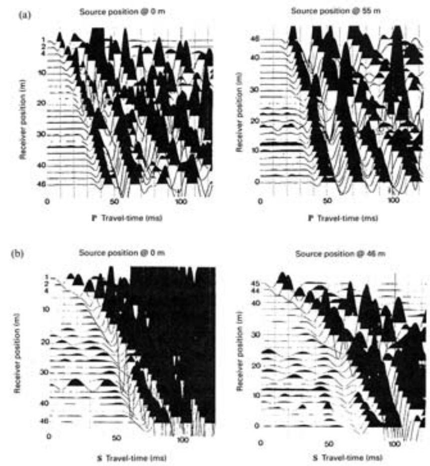


Fig. 4.53 Seismograms recorded on line 8 (see Fig. 4.54b) of the later survey at Vindobala Fort. (a) Forward and reverse P-wave records with 200 Hz low-pass filter. (b) Forward and reverse S-wave records with 100 Hz low-pass filter. P-wave records are distinctly better. (After Goulty and Hudson, 1994.)

Examples
Archeological investigations

(a)

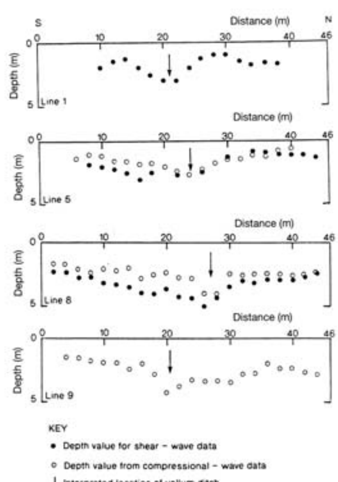


Fig. 4.54 (a) Depth profiles obtained along selected seismic lines (1, 5, 8, and 9).

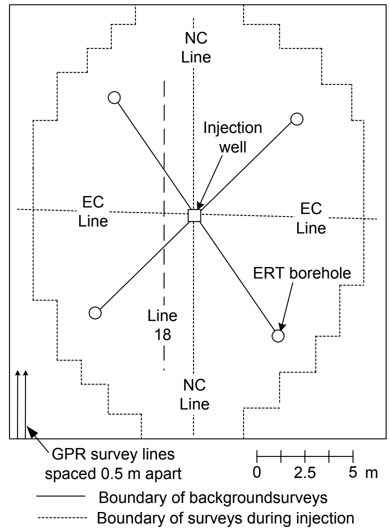
Depth profiles used to identify the location of the vallum

Difference in P and S results give some indication of uncertainty

Fig. 4.54 (b) Locations of the seismic lines (1 to 9), with the interpreted course of the vallum ditch. (After Goulty and Hudson, 1994).

Air sparging:

Testing effectiveness



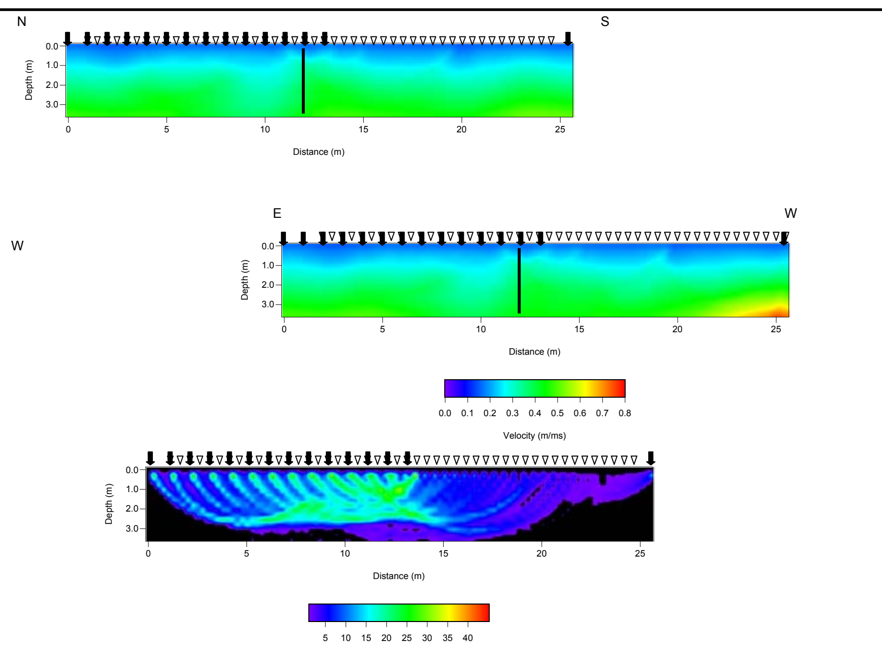


Figure 6 – (a) Velocity model for background refraction data along line EC. (b) Velocity model for background refraction data along line (NC). (c) Ray density for the velocity image of the background refraction data collected along line EC shown in (a). Areas that are black have a ray density less than unity. Vertical black arrows and white triangles represent the shot and geophone locations,

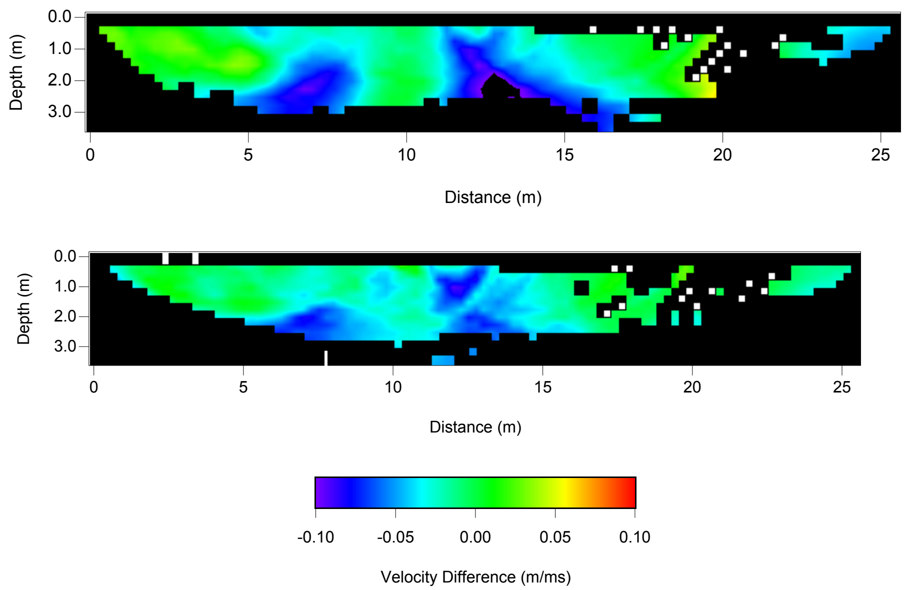


Figure 7 –Difference in velocity between injection and background refraction images collected along (a) line EC, and (b) line NC. The regions that are black have a ray-path density less than unity in either the background or injection images, and thus are not constrained by the data.

Examples

Quarry survey

Identifying location and thickness of sand and gravel deposits

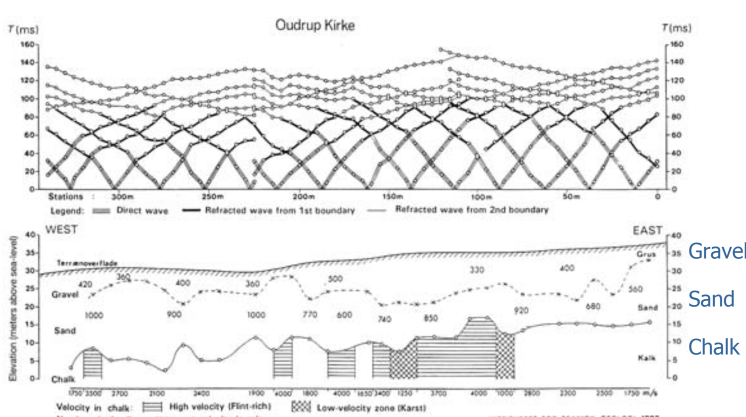


Fig. 4.55 Seismic refraction profile in an area of Quaternary sedimentary deposits, Oudrup Kirke, Denmark. Interpretation of the travel-time curves indicated the presence of three layers corresponding to the gravel, sand, and chalk formations. Note the relatively large lateral velocity changes in the chalk. (After Klitten, 1987.)

Examples

Crustal structure of the Alps

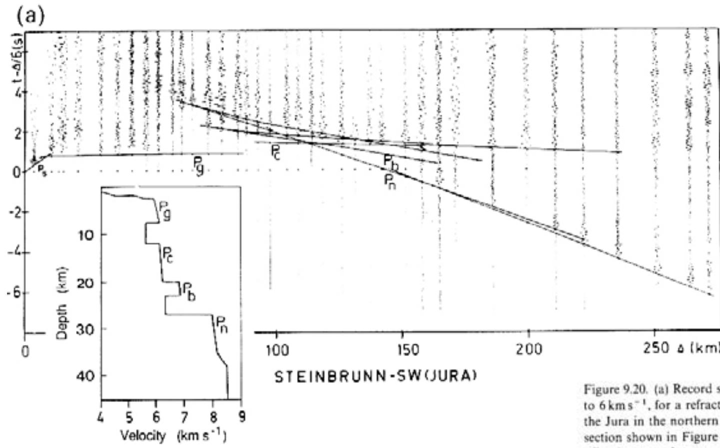
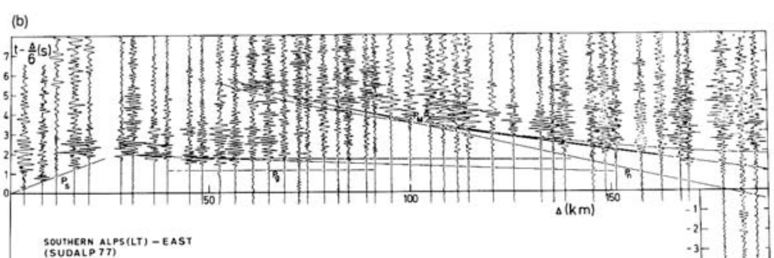


Figure 9.20. (a) Record section, reduced to 6 km s^{-1}, for a refraction line shot in the Jura in the northern part of the cross section shown in Figure 9.21b. The time offset between the crustal phases P_g and P_c indicates the presence of a low-velocity zone. Likewise, the low-velocity zone at the base of the crust is indicated by the time offset between phase P_b and the Moho reflection. (b) Record section.

Examples

Crustal structure of the Alps



Note the strong postcritical reflections (PmP)

- Suggests large velocity contrast across the Moho