Terrestrial seismic reflection profiling

Principles of operation

Earth materials exhibit a range of seismic velocities. Seismic waves striking boundaries between contrasting materials at 90º (*normal incidence*) will undergo a partial reflection of energy, whereby a proportion of the wave energy is reflected and the remainder is transmitted deeper into the ground. Measuring the time required for passage of seismic energy to boundaries and back to the surface (*two way travel time*, TWTT) facilitates determination of the subsurface structure.

Terrestrial seismic reflection surveying requires three components: a seismic source to generate the signal, a signal-enhancement seismograph to control the survey and record the data, and a series of geophones to detect the arrival of seismic waves at multiple points on the ground surface (Figure 1). Shallow surveys typically utilise a sledgehammer or Buffalo Gun source; deeper penetration can be achieved by firing small explosive charges several metres below ground level or an accelerated weight drop at the surface. For convenience, the passage of seismic energy through the ground is usually represented as raypaths, although the energy is actually travelling as waves (Figure 1). During their downward passage the seismic waves undergo partial reflection at interfaces between media of contrasting physical properties, particularly density. These reflections are detected by geophones at the surface and recorded on the digital seismograph, each record being termed a seismic *trace*. Each geophone produces a trace that shows reflection events as they occurred during the time elapsed following source activation. Advancing the source position along the geophone array generates a series of records that can later be corrected for the effects of array geometry. A typical survey line might comprise 48 geophones and 60-100 shotpoints. Accurate measurement of the height and spacing of each point on the line is critical to ensuring quality post-processing of the data.

Seismic reflection profiling requires specialised computer processing to correct each trace for geometric distortion. Any given point on a subsurface horizon is likely to be sampled several times during the survey (this multiplicity of coverage is termed the survey *fold*) and signals from each point can be summed to improve the signal to noise ratio (SNR). The final product from seismic reflection profiling is a stacked seismic section, examples of which are shown in Figures 2 and 3.

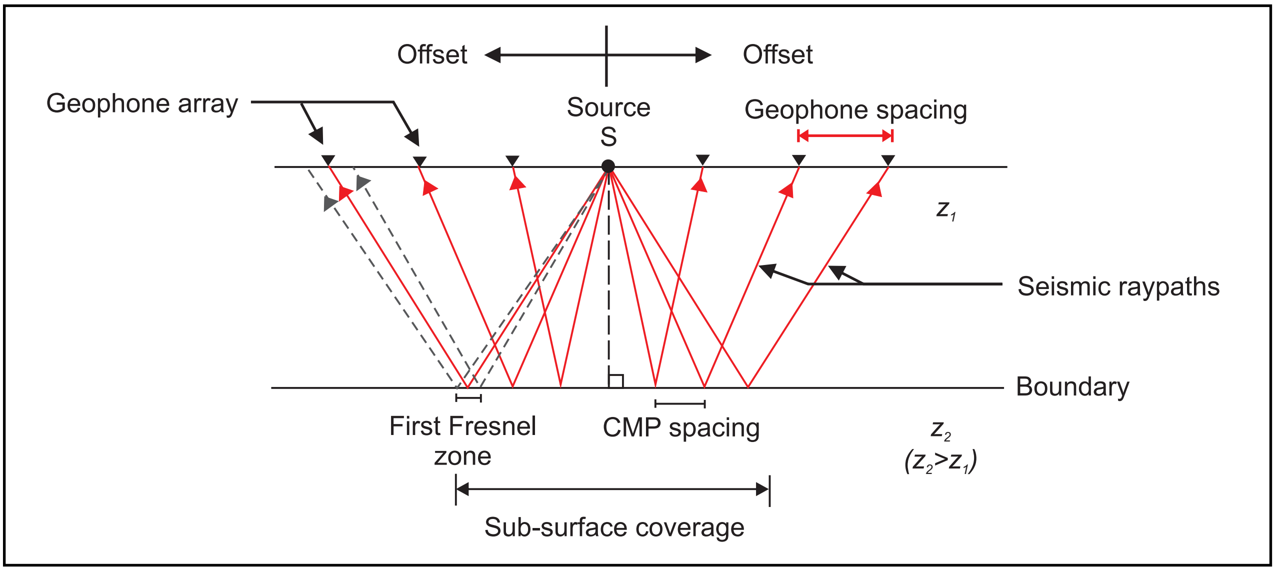

Figure 1: Schematic of reflection raypaths over a horizontal interface between materials of differing acoustic impedance (z), where $z_2 > z_1$.

If the seismic velocity for different horizons is known from boreholes or can be deduced from refraction data or complex velocity analysis computer routines, TWTT information can be translated into true depth sections. For example, Figure 3 (overleaf) has two axes: the right-hand vertical axis shows TWTT (milliseconds) but the left-hand axis shows converted depth (m). The seismic reflection method is described in considerable detail with many case histories by Reynolds (2011).

Applications

The most common applications of seismic reflection profiling on land are in mapping Quaternary sequences, hydrogeological investigations, and in engineering projects, typically for determining the shallow geological structure. Marine investigations also use the reflection technique routinely; this branch of geophysics is described in RIL Technical Summary Sheets #14 and 15.

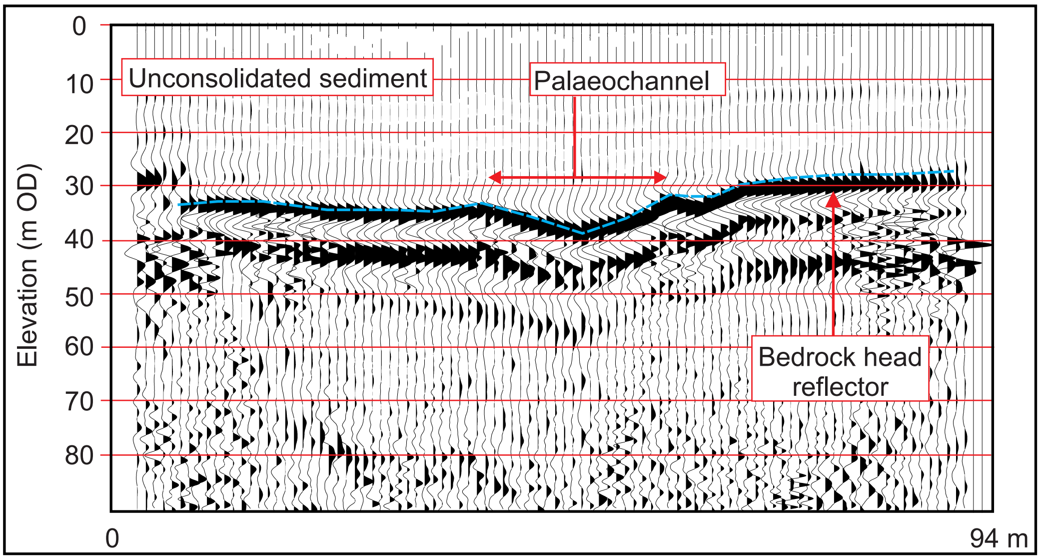

Figure 2: Seismic reflection section from a survey to detect sandstone bedrock beneath unconsolidated sediments in the Mersey Estuary, UK.

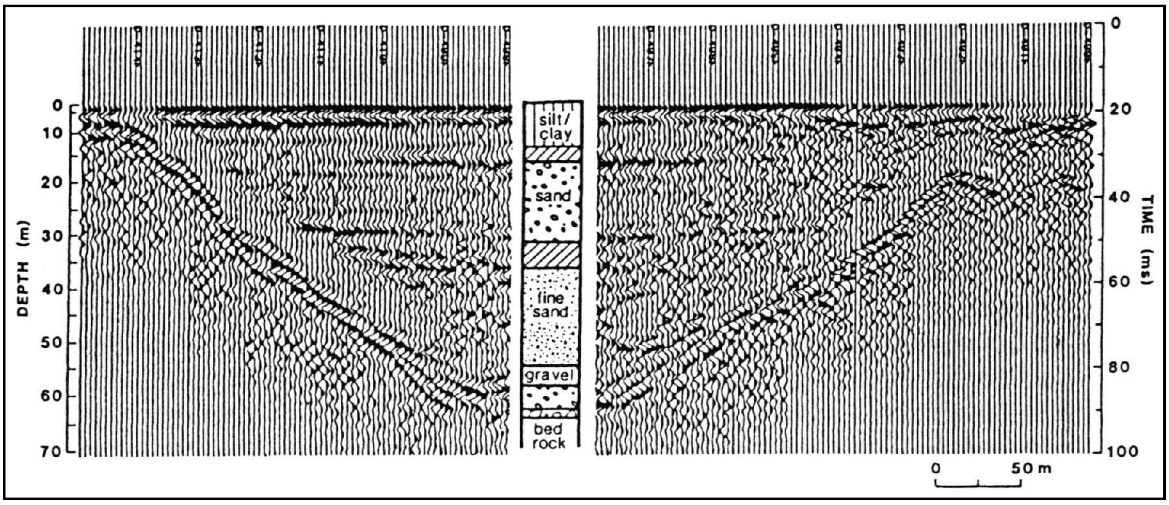

Figure 3: Seismic reflection section from Dryden, Ontario, showing a steep-sided valley in the bedrock, filled with clay and sand deposits, from Pullan and Hunter (1990), by permission. The section is approximately 500 m in length.

References

Pullan, S.E. and Hunter, J.A. (1990). Delineation of buried bedrock valleys using the optimum offset shallow seismic reflection technique. In: Ward, S.H. (ed.), *Geotechnical and Environmental Geophysics. Vol. 3: Geotechnical.* Tulsa: Society of Exploration Geophysicists, 75-87.

Reynolds, J.M. 2011. *An Introduction to Applied and Environmental Geophysics.* John Wiley & Sons Ltd, Chichester, 2nd ed., 712 pp.

