SEISMIC REFRACTION AND REFLECTION METHODS

GEO*Vision* geophysicists conduct high-resolution seismic refraction and seismic reflection surveys in support of a variety of engineering, environmental, and hydrogeologic investigations.

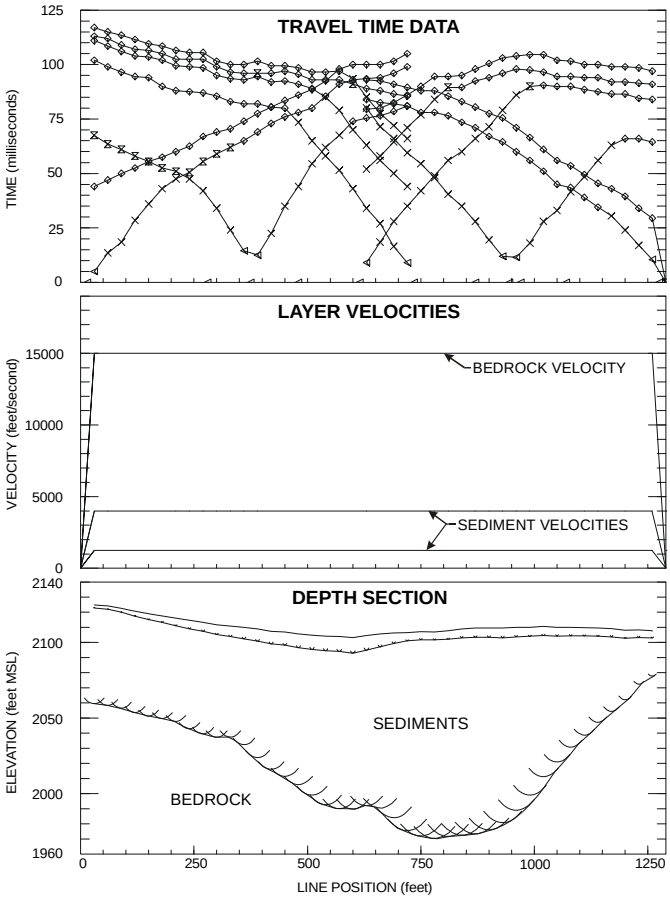
When conducting seismic surveys, acoustic energy is input to the subsurface by an energy source such as a sledgehammer impacting a metallic plate, weight drop, vibratory source, or explosive charge. The acoustic waves propagate into the subsurface at a velocity dependent upon the elastic properties of the material through which they travel. When the waves reach an interface where the density or velocity changes significantly, a portion of the energy is reflected back to the surface, and the remainder is transmitted into the lower layer. Where the velocity of the lower layer is higher than that of the upper layer, a portion of the energy is also critically refracted along the interface. Critically refracted waves travel along the interface at the velocity of the lower layer and continually refract energy back to surface. Receivers (geophones), laid out in linear array on the surface, record the incoming refracted and reflected waves. The seismic refraction method involves analysis of the travel times of the first energy to arrive at the geophones. These first arrivals are from either the direct wave (at geophones close to the source), or critically refracted waves (at geophones further from the source). The seismic reflection method involves the analysis of reflected waves, which occur later in the seismic record.

GEO*Vision* typically uses the Oyo DAS-1 or Geometrics R24/60 seismograph for refraction and reflection investigations. Seismic energy sources used on past projects have included a sledgehammer, Betsy Seisgun™, EG&G Geometrics Dynasource (a vacuum-assisted weight drop), Bison Elastic Wave Generator (accelerated weight drop), IVI Minivib, and explosives.

GEO*Vision* geophysicists use the seismic refraction method to:

- **Map bedrock topography**
- **Map faults in bedrock**
- **Estimate depth to groundwater**
- **Estimate bedrock rippability**
- **Evaluate rock properties**

Seismic Refraction Survey in Imperial Valley



Seismic Refraction Survey to Map Bedrock Topography

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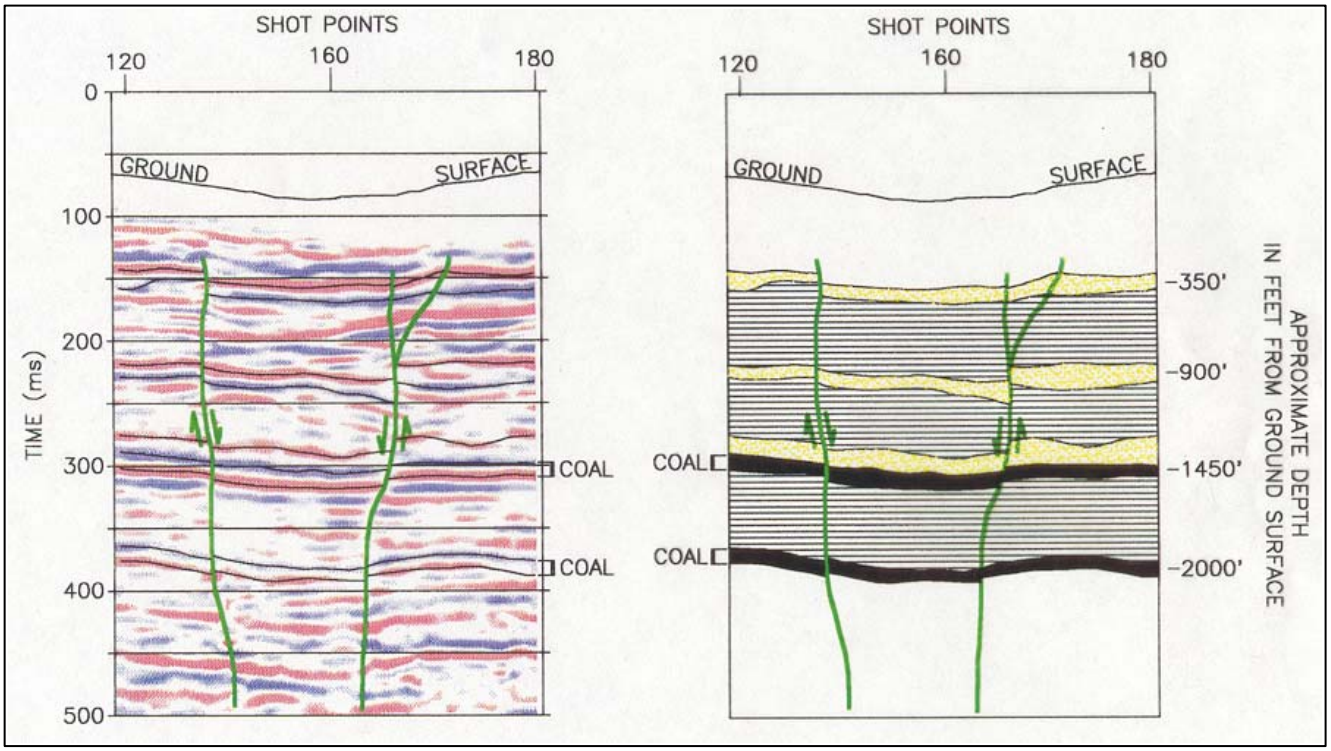
GEO*Vision* geophysicists typically use the generalized reciprocal method (GRM) to analyze high-resolution seismic refraction data. Several computer programs are used in processing seismic refraction data including the program FIRSTPIX™ by Interpex, Ltd., which allows manual or automatic picking of first breaks, the program VIEWSEIS™ by Viewlog Systems, Ltd., which implements the GRM, and the program SeisOpt by Optim LLC for data modeling.

GEO*Vision* geophysicists use the seismic reflection method to:

- **Map subsurface stratigraphy**
- **Map lateral continuity of geologic layers**
- **Map buried paleo-channels**
- **Map faults in sedimentary layers**
- **Map basement topography**

GEO*Vision* geophysicists often use the program SPW by Parallel Geosciences to process seismic reflection data and the program 2Dpak by Seismic Micro-Technology Inc. for seismic interpretation. Processing steps generally applied to reflection data include format conversion, trace editing, pre-processing (description of field geometry), spectral whitening or deconvolution, velocity analysis, surface consistent statics, velocity analysis, normal moveout corrections, prestack filtering, prestack gains, residual statics, and migration.

IVI Minivib Seismic Reflection Source



Seismic Reflection Survey to Map Coal Seams