

GEOPHYS 242: Near Surface Geophysical Imaging

Class 3: Refraction Traveltime Interpretation

Fri, April 8, 2011

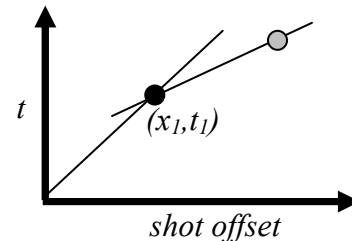
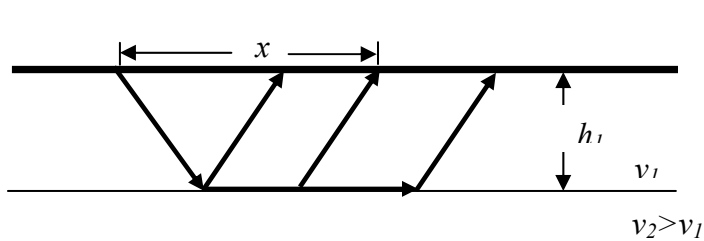
- Analytical refraction solutions
- Detailed approach in delay-time method
- Generalized Linear Inversion (GLI) for layer model inversions
- Review of commercial software solutions

This class will start with Oz Yilmaz's presentation through the Internet about the near-surface examples. We will then introduce the conventional refraction traveltime methods for near-surface structure interpretation. These approaches produce layered models, appropriate for relatively simple velocity structures. Two influential approaches include delay-time method and generalized liner inversion method.

Analytical Refraction Solutions

Assuming 1D velocity structures with multiple layers and velocity increasing with depth, we can derive an exact analytical solution from refraction traveltimes.

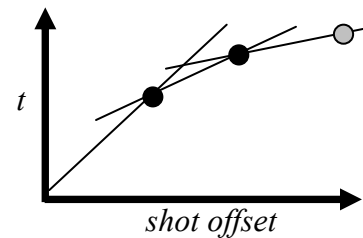
Two-Layer Model (One layer over half a space):



$$t_1 = x_1/v_2 + 2h_1(v_2^2 - v_1^2)^{1/2}/(v_2v_1) \quad (1)$$

Three-Layer Model (Two layers over half a space):

$$t_2 = x_2/v_3 + 2h_1(v_3^2 - v_1^2)^{1/2}/(v_3v_1) + 2h_2(v_3^2 - v_2^2)^{1/2}/(v_3v_2) \quad (2)$$



N-Layer Model

$$t_{n-1} = x_{n-1}/v_n + (2/v_n)\sum h_i(v_n^2 - v_i^2)^{1/2}/v_i \quad (3)$$

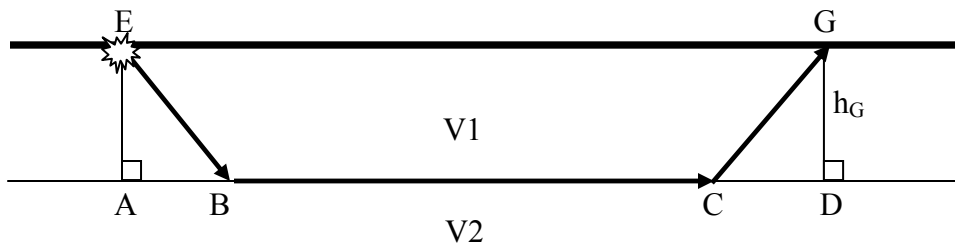
$$t_{n-1} = a_0 x_{n-1} + a_1 h_1 + a_2 h_2 + a_3 h_3 + \dots \quad (3a)$$

Notes:

- Other analytical solutions – multiple dipping interfaces
- All analytical solutions _ assume velocity increasing with depth
- Hidden layers – refraction methods fail
- Any other structures – no analytical solutions, need to be derived otherwise
- All approaches are under some assumptions

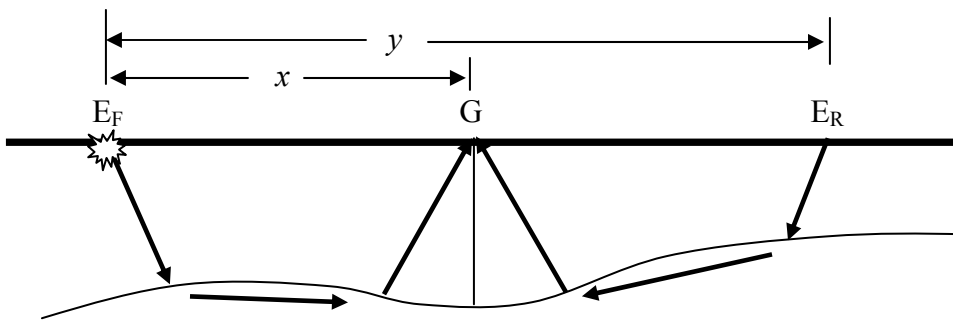
Delay-Time Method

Map irregular refractor interfaces



Total delay time for source and receiver: $T_{EG} = T_E + T_G$ (1)

Delay-time at G: $T_G = CG/v_1 - CD/v_2 = h_G ((v_2^2 - v_1^2)^{1/2} / (v_1 v_2))$ (2)



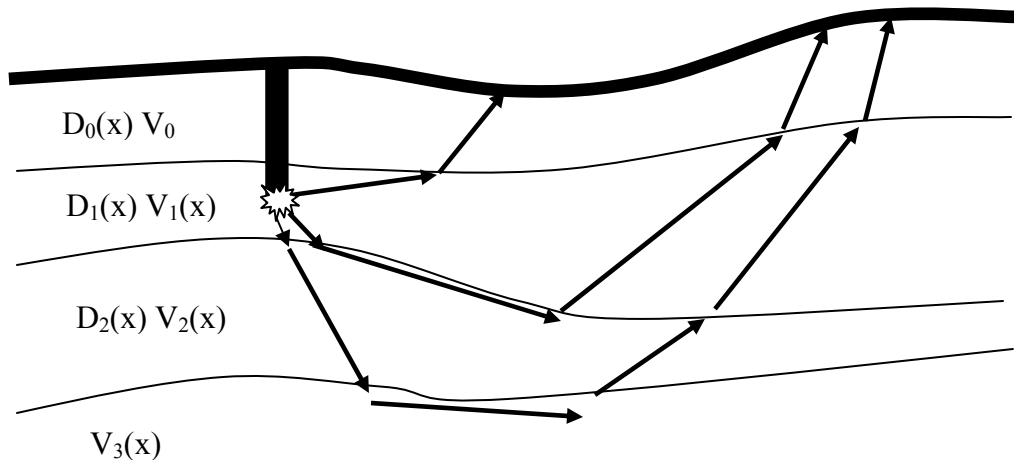
Derive reliable v_2 when the interface varies:

$t_{EFG} - t_{ERG} = T_{EF} - T_{ER} + 2x/v_2 - y/v_2$ (3)

Questions: what are the assumptions behind the delay-time method?

Generalized Linear Inversion (GLI) for Layer Models

By Hampson and Russell (1984)



Objective: given traveltimes observed at the surface, invert layer depths $D_i(x)$, and velocity $V_i(x)$

Model: $M=(m_1, m_2, m_3 \dots, m_m)$ (thickness and **slowness**)
 Data: $T=(t_1, t_2, t_3, \dots, t_n)$ (direct-wave and refraction arrivals)

Physics: $t_i=A_j(m_1, m_2, m_3 \dots, m_m), i=1,2,3, \dots n.$
 Given a velocity model and geometry, generate traveltimes of rays

Inverse Problem:

$$B\Delta M=\Delta T$$

$$B_{ij}=\partial t_i/\partial m_j$$

Objective Function: $\psi = ||T - A(m)||^2$

Model Update: $\Delta M=(B^T B)^{-1} B^T \Delta T$
 $M=M+\Delta M$

A more sophisticated inversion scheme:

Objective Function: $\psi = ||T - A(m)||^2 + \tau ||L(m)||^2$
 Solving an inverse problem:

$$(B^T B + \tau L^T L)\Delta M=B^T \Delta T - \tau L^T L(M)$$

Commercial Software Packages:

Delay-Time Solutions:

Fathom:	Green Mountain Geophysics (ION), Denver, CO
Seismic Studio:	FusionGeo, Houston, Texas
TomoPlus:	GeoTomo, Houston, Texas

Generalized Linear Inversion:

GLI3D:	Hampson-Russell, Calgary, Canada
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