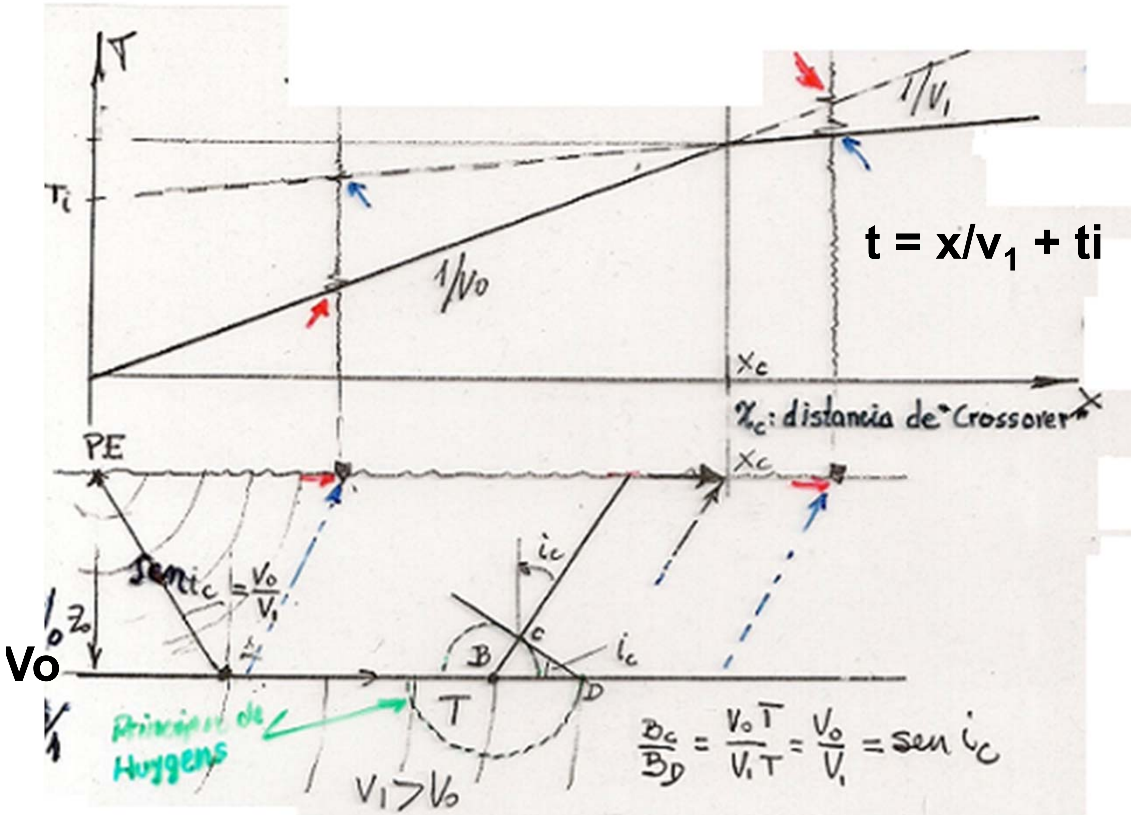
Sísmica
-Clase 2-

SÍSMICA DE REFRACCIÓN

Principio físico de la Sísmica de Refracción.
REFRACCIÓN CRÍTICA



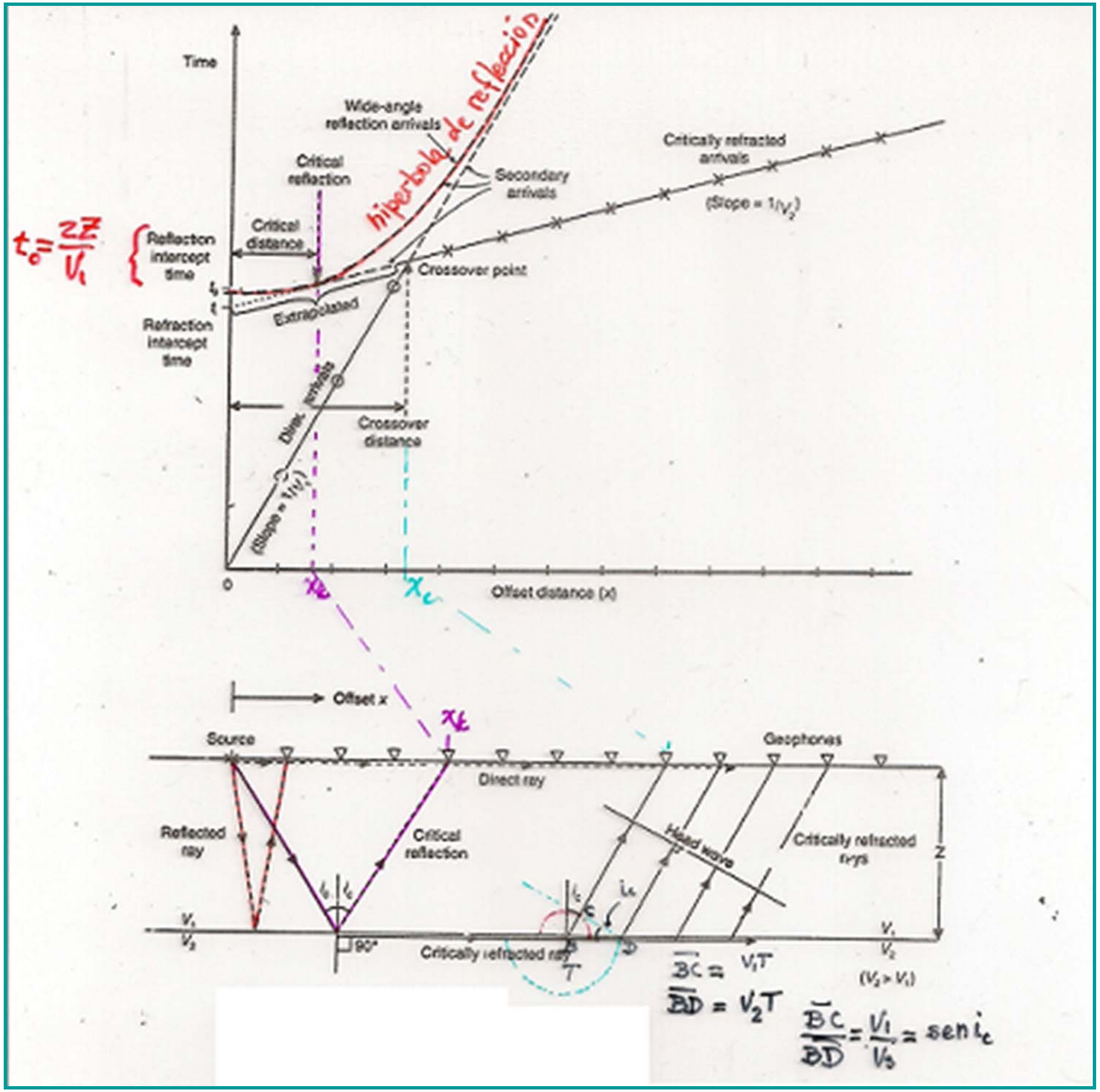
Dromocrona Horizontal

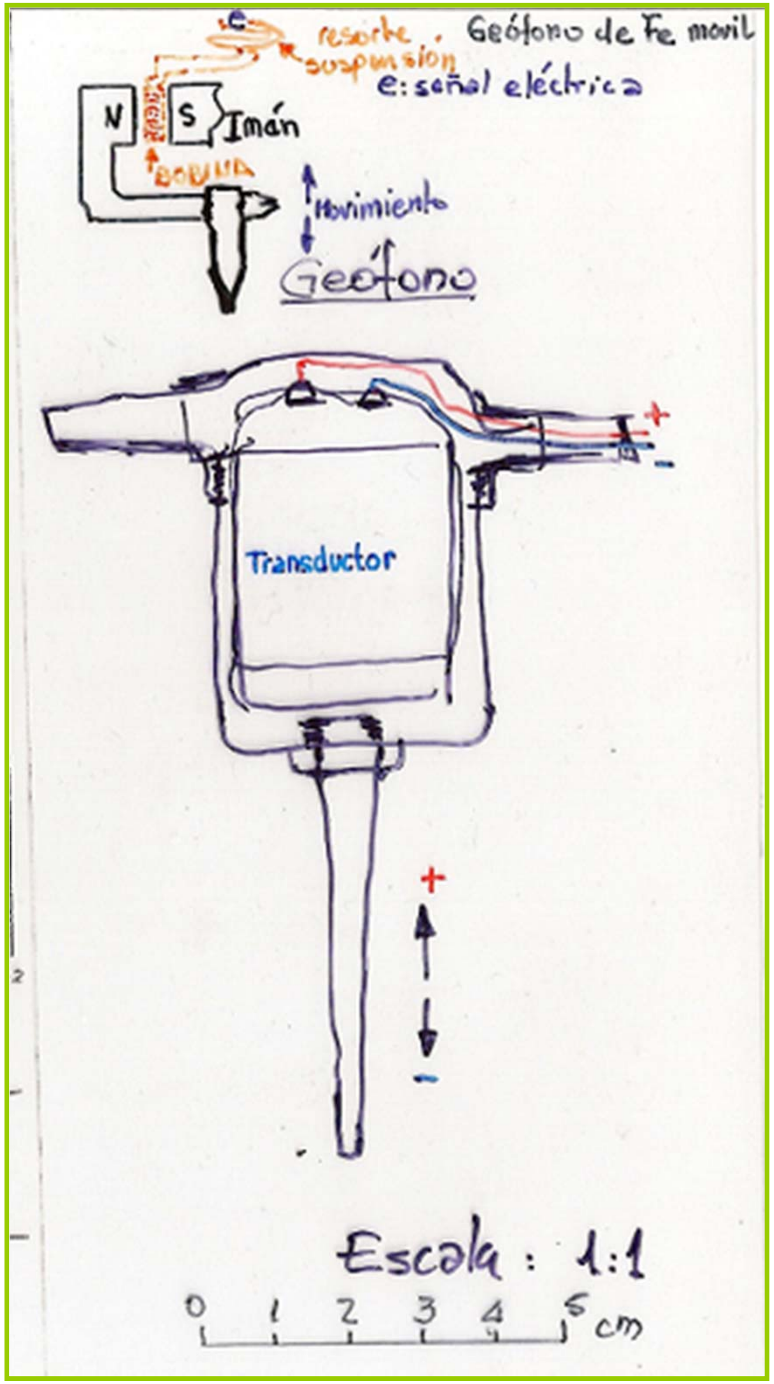
Gráficos **x** vs **t** para los distintos geófonos. Permite:

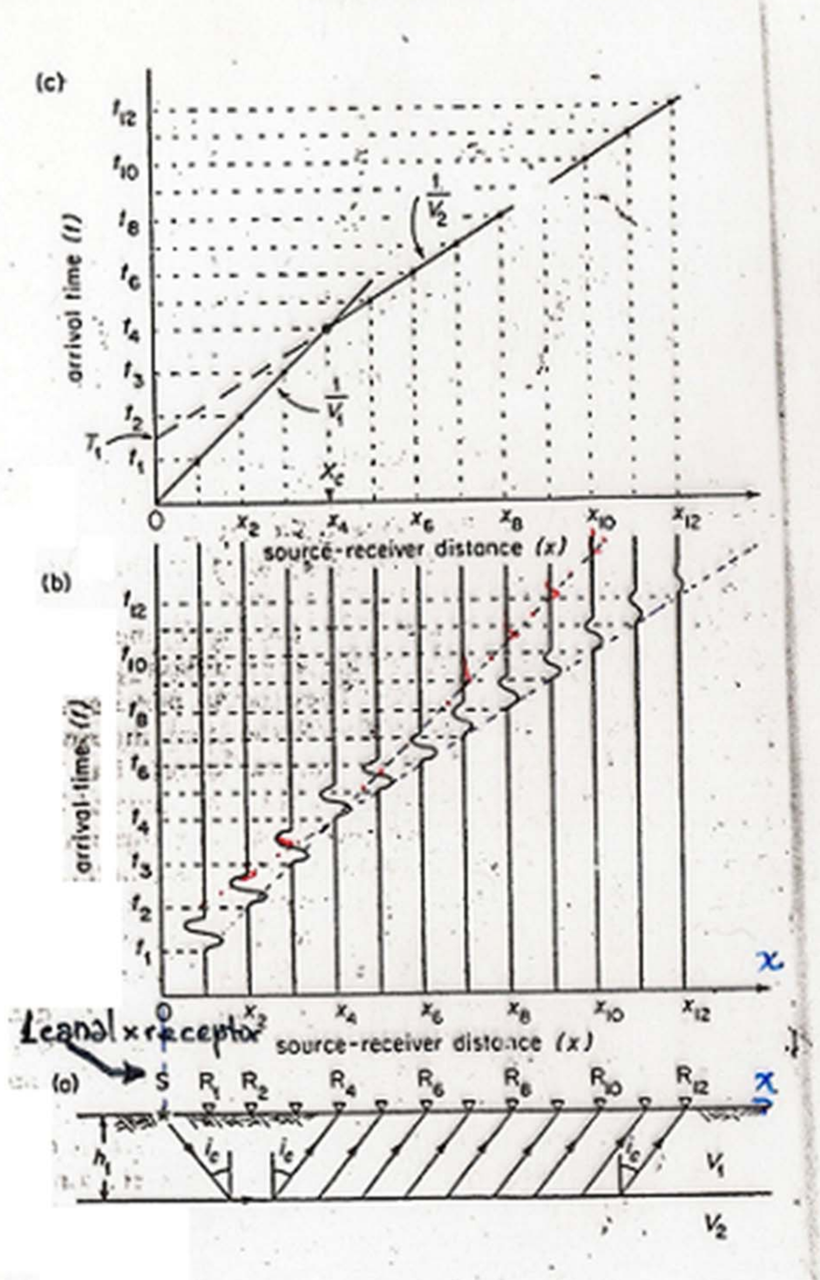
- Medir velocidades y espesores de las distintas capas
- Medir buzamiento de las capas

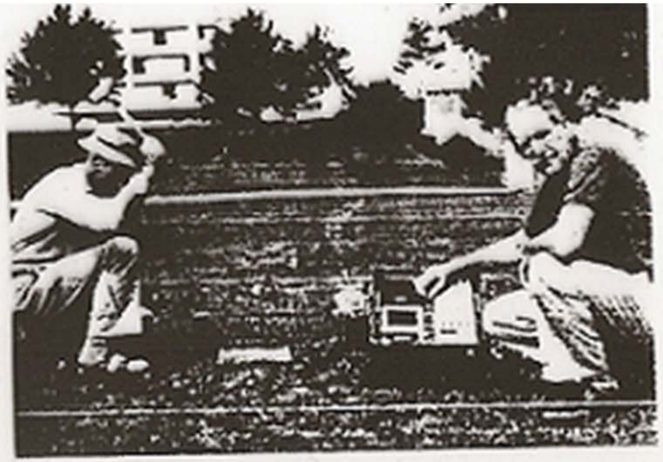
2 capas horizontales →

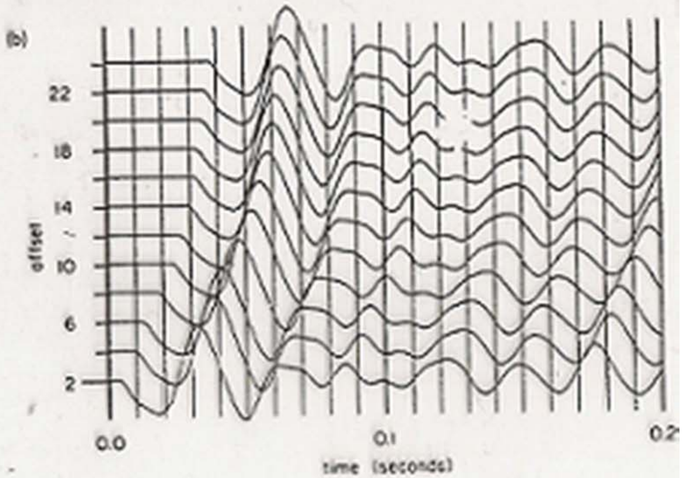
$$Z_0 = \frac{X_c}{2}\sqrt{\frac{V_1 - V_0}{V_1 + V_0}} = \frac{T_i}{2}\frac{V_1 V_0}{\sqrt{V_1^2 - V_0^2}}$$

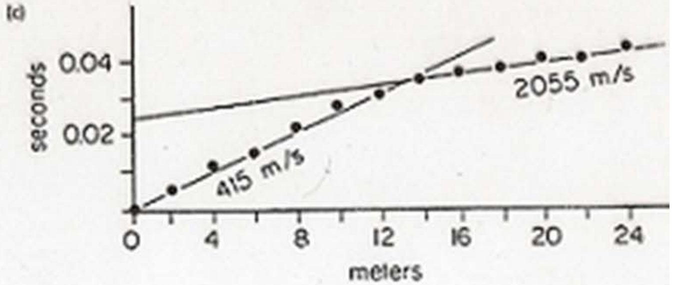

Time
Wide-angle reflection arrivals
hiperbola de reflexión
Critical reflection
Secondary arrivals
Critically refracted arrivals
(Slope = 1/V2)
Critical distance
Reflection intercept time
t0 = 2Z/V1
Crossover point
Extrapolated
Refraction intercept time
Direct arrivals
(Slope = 1/V1)
Crossover distance
0
xt
xc
Offset distance (x)
Offset x
Source
Geophones
Direct ray
Reflected ray
Critical reflection
Head wave
Critically refracted rays
Z
V1
V2
90°
Critically refracted ray
(V2 > V1)
BC = V1T
BD = V2T
BC/BD = V1/V2 = sen ic


e
resorte
Geófono de Fe movil
suspensión
e: señal eléctrica
N
S
Imán
BOBINA
Movimiento
Geófono
Transductor
+
-
+
-
Escala : 1:1
0 1 2 3 4 5 cm


(c)
arrival time (t)
source-receiver distance (x)
(b)
arrival time (t)
source-receiver distance (x)
(a)
S R1 R2 R4 R6 R8 R10 R12
V1
V2




(b)
offset
time (seconds)
0.0
0.1


(c)
seconds
0.04
0.02
2055 m/s
415 m/s
meters
0 4 8 12 16 20 24

Introducing the ES-2401 Exploration Seismograph.

Now there's an easier way to get high-resolution survey data — and get better results too.

The *new* EG&G Geometrics ES-2401 Exploration Seismograph just changed the way shallow reflection, refraction or tomographic surveys will be conducted. It also sets a new standard for field performance,

providing improved results independent of survey personnel skill levels.

Gather field data faster, with better results.

High resolution data is acquired with instantaneous floating point amplifiers and 15-bit A/D converters stacked into a 32-bit memory. With no manual gain controls and this much resolution, you can acquire and process reflection data with simple field procedures, and in a wide range of geologic conditions.

Store survey data in the field — analyze it on your PC before the next day's survey.

The ES-2401 stores field data on internal, PC-compatible media (3.5″ floppy, or cartridge) for on-site analysis after each day's survey, or later in the office. Using Geoflex™ software from EG&G Geometrics, reflection and refraction field data can be easily read and processed on most PC's. The ES-2401 is made for refraction work too. Field data is stored digitally and can be displayed at different trace sizes and scales, or used for digital filtering, or even picking first arrivals automatically.

The backpack portable with the features you'd expect.

Because it's made by EG&G Geometrics, the ES-2401 is competitively priced and is loaded with features. Like 12 or 24 channels. A large 640 x 400 dot backlit LCD display. Built-in thermal plotter. Lowcut, notch and highcut filters. Battery powered. And more.

Want better survey results with less hassle? Contact EG&G Geometrics today for details on the *new* ES-2401.

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GEOMETRICS

Geode Ultra-Light Exploration Seismograph

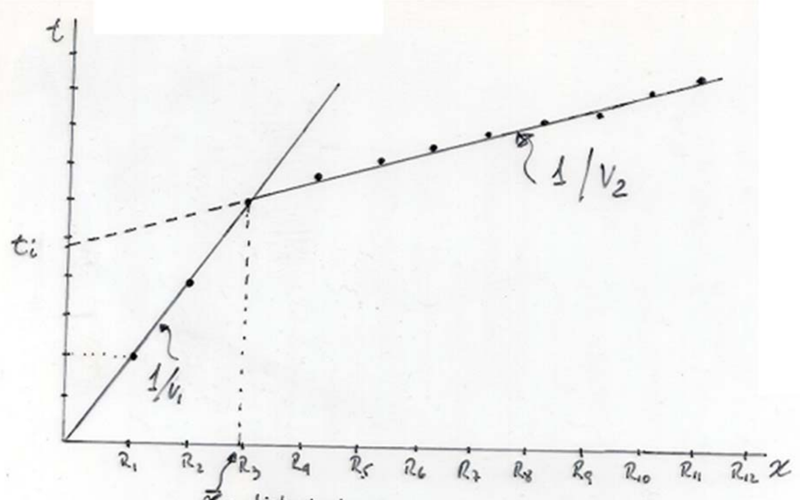
Geodes operate from either your laptop or from Geometrics StrataVisor NZ field computer

The StrataVisor NZ with daylight visible color screen and built-in plotter is weather and shock resistant

OYO

OYO Corporation

McSEIS-SX48



x: distancia de cruce.

t_i: tiempo de intercepción

Onda refractada $\Rightarrow t_2 = \frac{SA + RB}{v_1} + \frac{AB}{v_2} = \frac{2h_1}{v_1 \cos i_c} + \frac{AB}{V_2} = \frac{2h_1}{v_1 \cos i_c} + \frac{x - AC - BD}{v_2}$

$SA = RB = \frac{h_1}{\cos i_c}$

$AC = BD = h_1 \, tg \, i_c$

$$t_2 = \frac{2h_1}{v_1 \cos i_c} + \frac{x}{v_2} - \frac{2h_1 \, tg \, i_c}{v_2}$$

$$t_2 = \frac{x}{V_2} + \frac{2h_1}{v_1 \cos i_c}\left(1 - \frac{v_1}{v_2} \operatorname{sen} i_c\right) \quad \text{pero } \frac{v_1}{v_2} = \operatorname{sen} i_c$$

$$t_2 = \frac{x}{V_2} + \frac{2h_1}{v_1 \cos i_c}\left(1 - \operatorname{sen}^2 i_c\right)$$

2 capas horizontales con $v_1 < v_2$

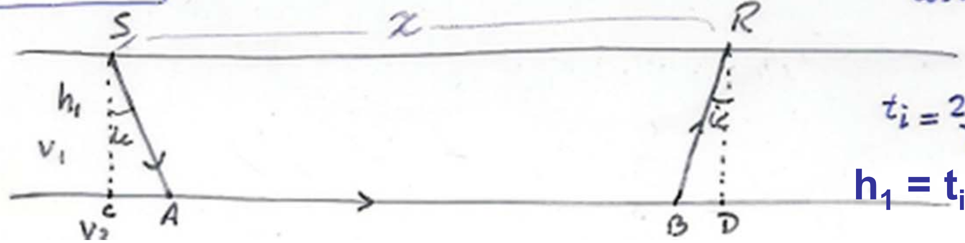
$$h_1 = \frac{t_i}{2} \cdot \frac{v_1 v_2}{\sqrt{v_2^2 - v_1^2}}$$

$$t_2 = \frac{x}{v_2} + \frac{2h_1 \cos i_c}{v_1}$$

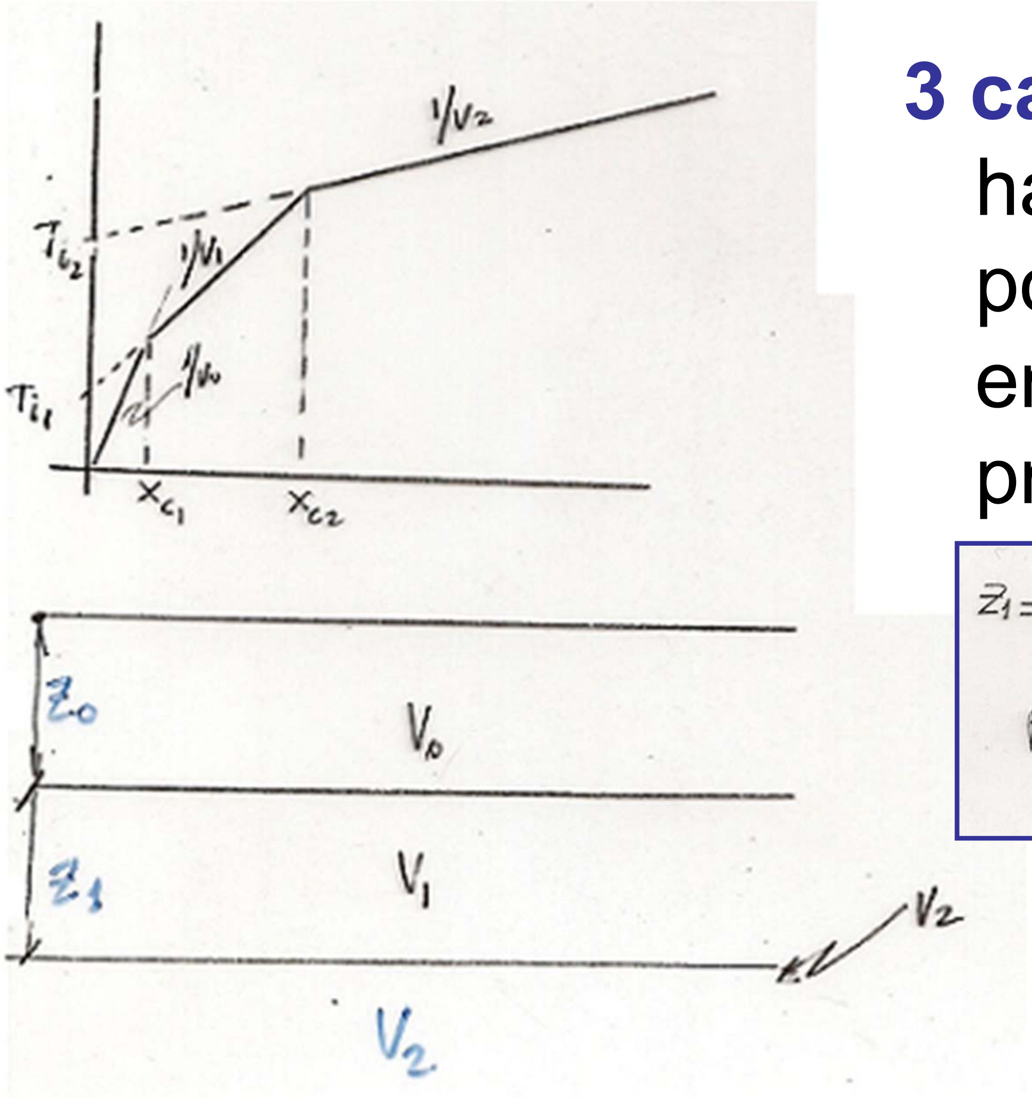
$$t_i = \frac{2h_1 \cos i_c}{v_1}$$

$$\cos i_c = \sqrt{1 - \operatorname{sen}^2 i_c} = \sqrt{1 - \left(\frac{v_1}{v_2}\right)^2}$$

$$t_i = \frac{2h_1}{v_1}\sqrt{1 - \left(\frac{v_1}{v_2}\right)^2}$$



$h_1 = t_i v_1 / 2(1 - (v_1/v_2)^2)^{1/2}$



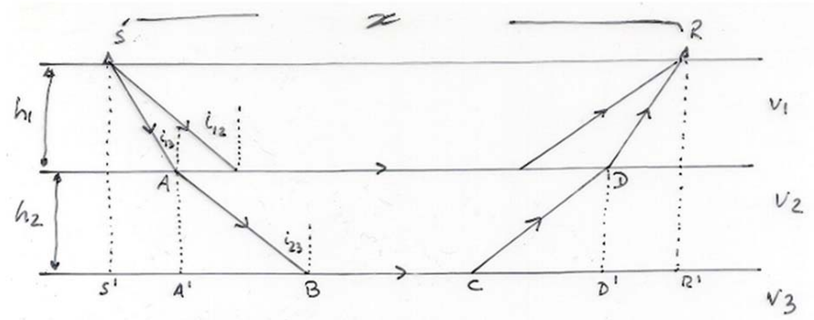
3 capas horizontales:

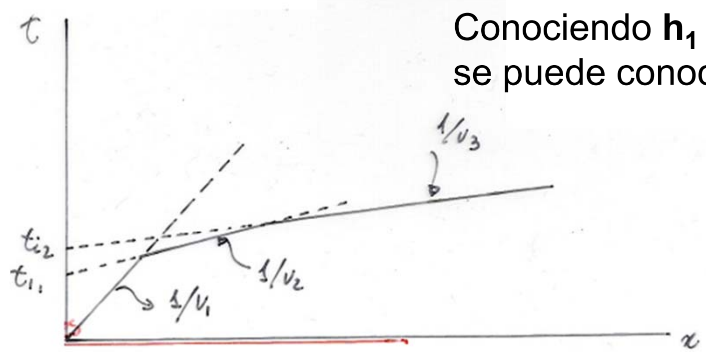
hay que calcular z_0, por lo tanto los errores en z_0 se propagan a z_1.

$$Z_1 = \frac{1}{2}\left(T_{i_2} - \frac{2 Z_0 \sqrt{V_2^2 - V_0^2}}{V_2 V_0}\right) \frac{V_2 V_1}{\sqrt{V_2^2 - V_1^2}}$$

prof. Total $= Z_0 + Z_1$

Cálculo de la velocidad y profundidad para varias interfases





Conociendo **h_1** por **t_i**, se puede conocer **h_2**.

$$t = \frac{SA+RD}{v_1} + \frac{AB+CD}{v_2} + \frac{BC}{v_3} = \frac{2h_1}{v_1\cos i_{13}} + \frac{2h_2}{v_2\cos i_{23}} + \frac{x-(2S'A'+2A'B)}{v_3}$$

$$t = \frac{x}{v_3} + \frac{2h_1}{v_1\cos i_{13}} + \frac{2h_2}{v_2\cos i_{23}} - \left(\frac{2h_1\,\mathrm{tg}\, i_{13} + 2h_2\,\mathrm{tg}\, i_{23}}{v_3}\right)$$

$$t = \frac{x}{v_3} + \frac{2h_2}{v_2\cos i_{23}}\left(1-\frac{v_2}{v_3}\,\mathrm{sen}\, i_{23}\right) + \frac{2h_1}{\cos i_{13}\, v_1}\left(1-\frac{v_1}{v_3}\,\mathrm{sen}\, i_{13}\right)$$

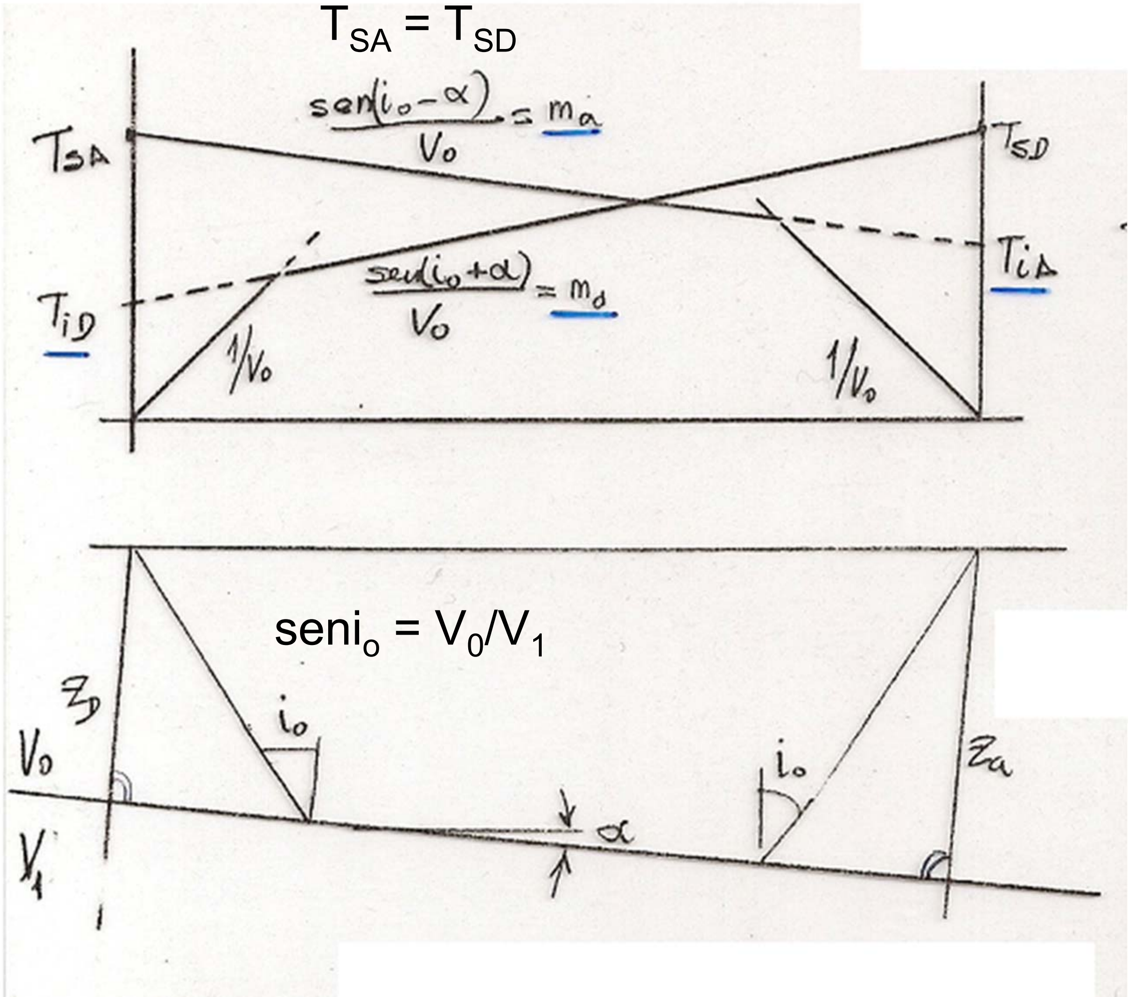
$$\boxed{t = \frac{x}{v_3} + \frac{2h_2}{v_2}\cos i_{23} + \frac{2h_1}{v_1}\cos i_{13}}$$

$$t_{i_2} = \frac{2h_2}{v_2}\cos i_{23} + \frac{2h_1}{v_1}\cos i_{13}$$

Generalizando para **n capas**:

$$\mathbf{t = x/v_{n+1} + 2\Sigma_{k=1}^{n} (h_k \cos i_{k-n+1})/ v_k}$$

Técnica del Perfil y Contraperfil
Caso 1: interfase inclinada



Datos obtenidos del Perfil-Contraperfil:

V_0, m_a, m_d

T_{iD}

T_{iA}

Técnica del Perfil y Contraperfil

Caso 1: interfase inclinada

Cálculo del buzamiento α e incidencia i_0

$$\alpha = \frac{1}{2}\left[\text{arc sen}(V_0\, m_D) - \text{arc sen}(V_0\, m_A)\right]$$

$$i_0 = \frac{1}{2}\left[\text{arc sen}(V_0\, m_D) + \text{arc sen}(V_0\, m_A)\right]$$

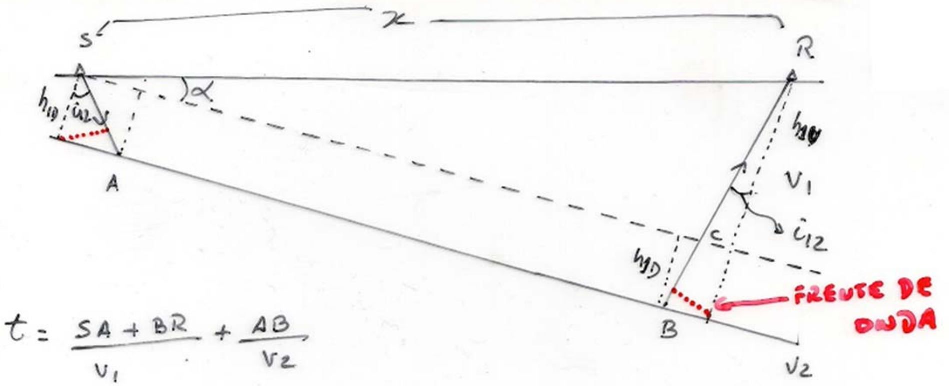
Cálculo de la velocidad real

$$V_1 = \frac{V_0}{\text{sen}\, i_0}$$

Cálculo de las profundidades

$$Z_D = \frac{V_0}{2}\,\frac{T_{iD}}{\cos i_0}$$

$$Z_A = \frac{V_0}{2}\,\frac{T_{iA}}{\cos i_0}$$



$$t = \frac{SA + BR}{V_1} + \frac{AB}{V_2}$$

$$t_D = \frac{x \cos\alpha}{V_2} + \frac{h_{1D} + h_{1U}}{V_1} \cos i_{12}$$

$$h_{1D} = h_{1U} - x \,\text{sen}\,\alpha$$

$$h_{1U} = h_{1D} + x \,\text{sen}\,\alpha$$

$$t_D = \frac{x}{V_2} \cos\alpha + \frac{2h_{1D} + x \,\text{sen}\,\alpha}{V_1} \cos i_{12}$$

$$t_{iD} = \frac{2h_{1D}}{V_1} \cos i_{12} \qquad t_{iU} = \frac{2h_{1U}}{V_1} \cos i_{12}$$

ahora $t_D = \dfrac{x}{V_D} + t_{iD}$ $\qquad t_U = \dfrac{x}{V_U} + t_{iU}$

$$V_D = \frac{V_1}{(\text{sen}\,(i_{12}+\alpha))} \qquad V_U = \frac{V_1}{(\text{sen}\,(i_{12}-\alpha))}$$

$$i_{12} + \alpha = \text{arc sen}\,\frac{V_1}{V_D} \Rightarrow \alpha = 1/2 \left(\text{arc sen}\,\frac{V_1}{V_D} - \text{arc sen}\,\frac{V_1}{V_U}\right)$$

$$i_{12} - \alpha = \text{arc sen}\,\frac{V_1}{V_U} \Rightarrow i_{12} = \frac{1}{2}\left(\text{arc sen}\,\frac{V_1}{V_D} + \text{arc sen}\,\frac{V_1}{V_U}\right)$$

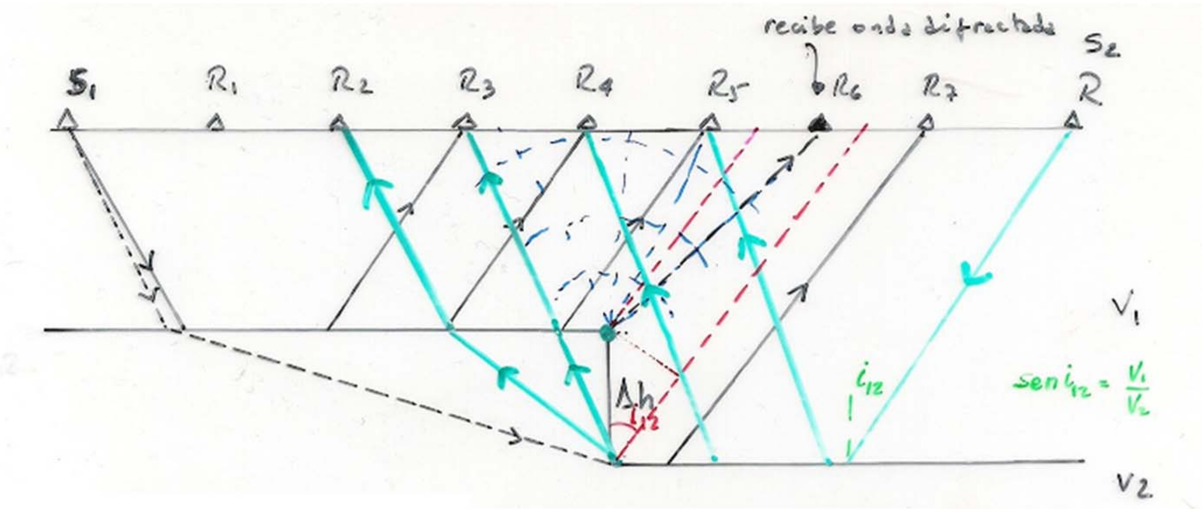
siendo $V_2 = \dfrac{V_1}{\text{sen}\, i_{12}} \Rightarrow i_{12} = \text{arc sen}\,\dfrac{V_1}{V_2}$ si i_{12} es pequeño

$$\frac{V_1}{V_2} \cong \text{arc sen}\,\frac{V_1}{V_2} \Rightarrow \boxed{V_2 \cong 2\left(\frac{V_D V_U}{V_D + V_U}\right)}$$

Técnica del Perfil y Contraperfil

Caso 1: interfase inclinada

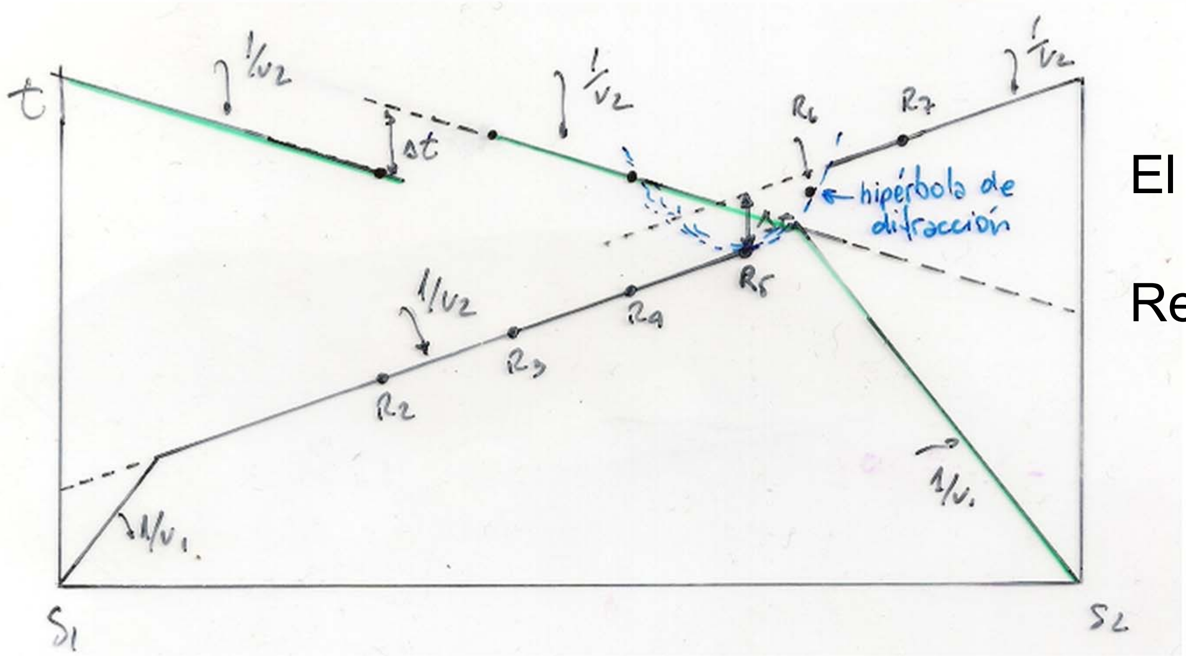
Técnica del Perfil y Contraperfil
Caso 2: horizonte discontinuo (FALLA)



Entre R_5 y R_7: salto en el tiempo de arribo.

R6 recibe onda difractada.

En el contraperfil también salto de tiempo, pero inverso.

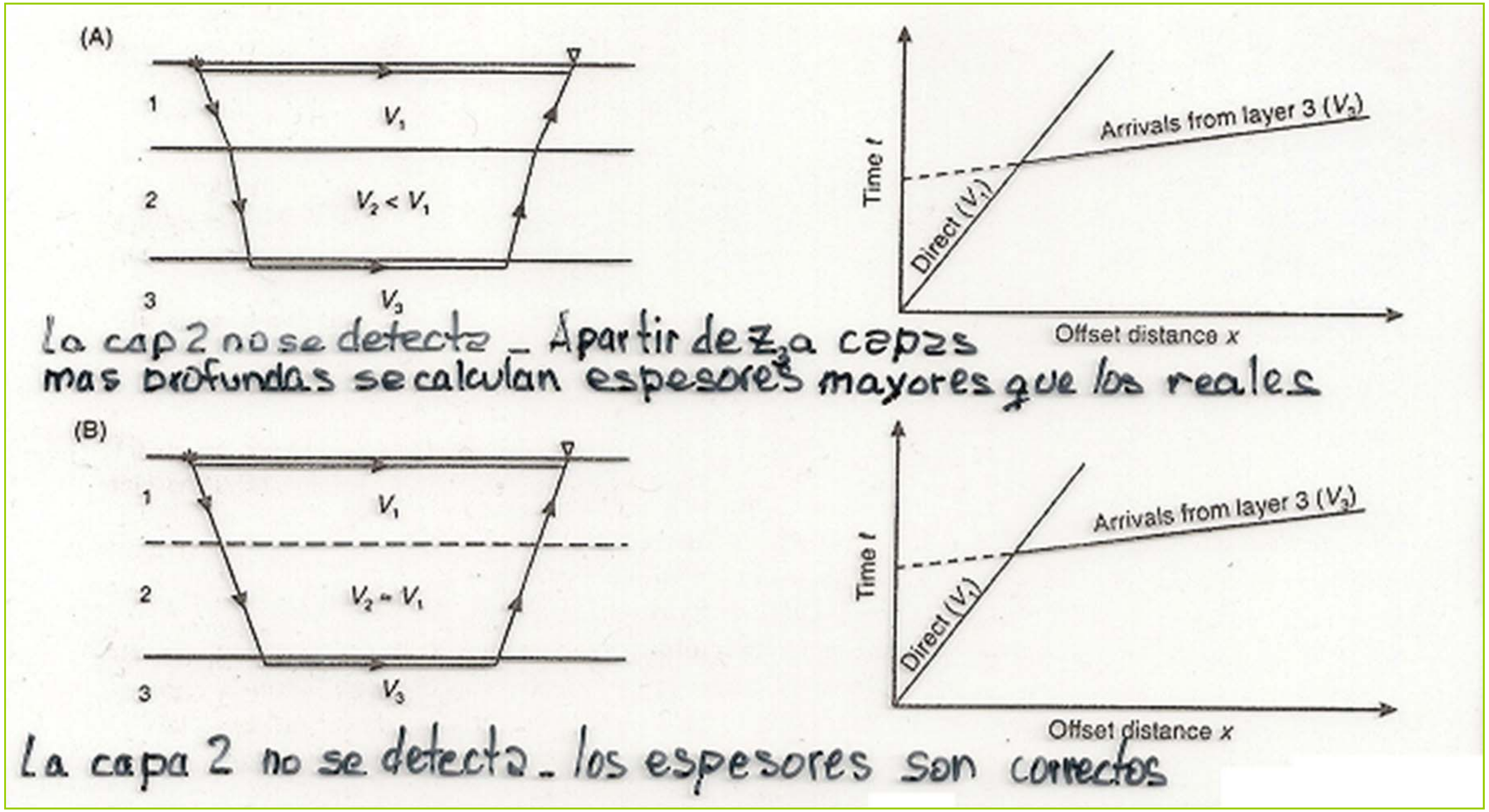


El salto se produce desplazado de la falla.

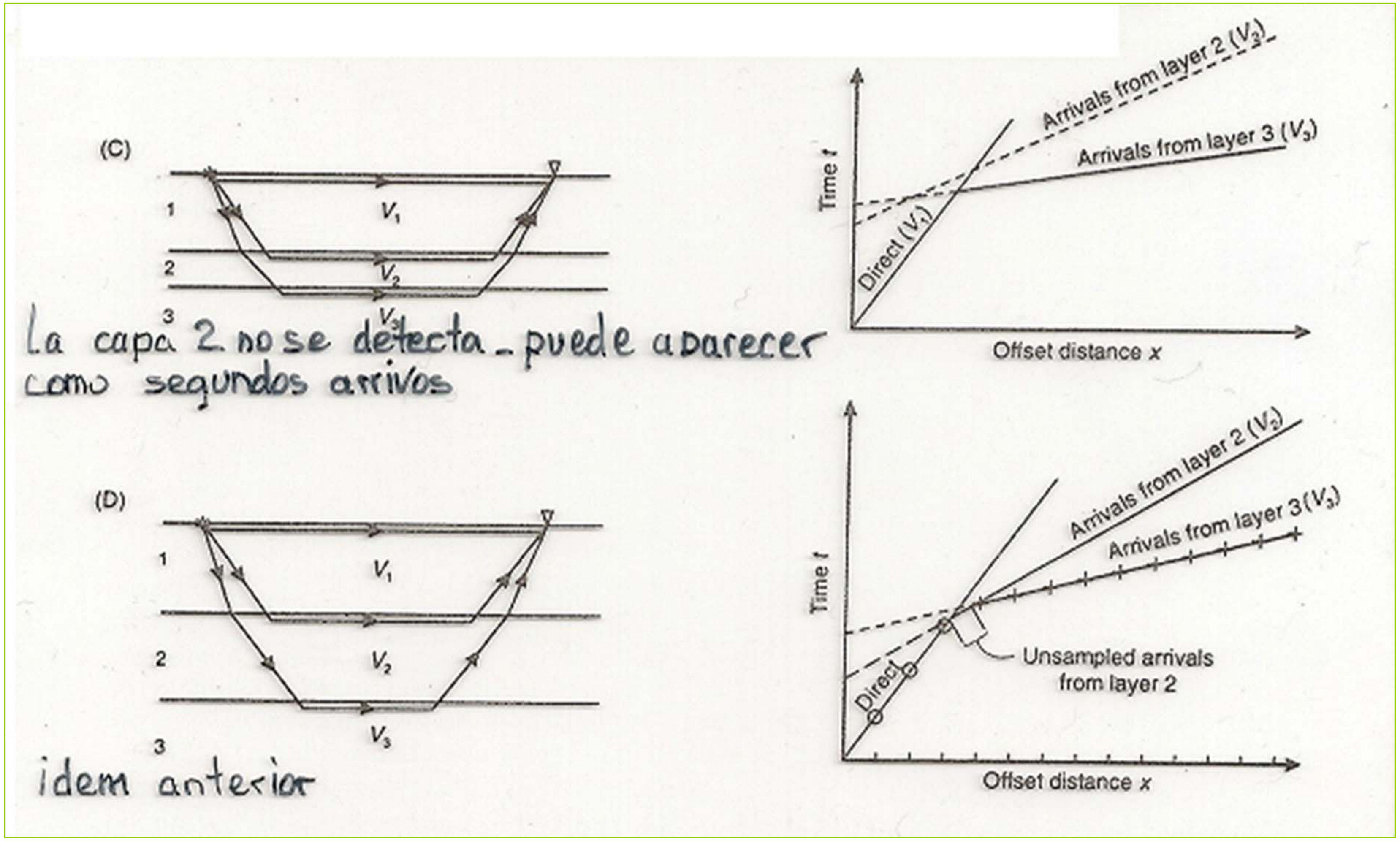
Rechazo de la falla:

$$\Delta h = \frac{\Delta t\, v_1}{\cos i_{12}} = \frac{\Delta t\, v_1\, v_2}{(v_2^2 - v_1^2)^2}$$

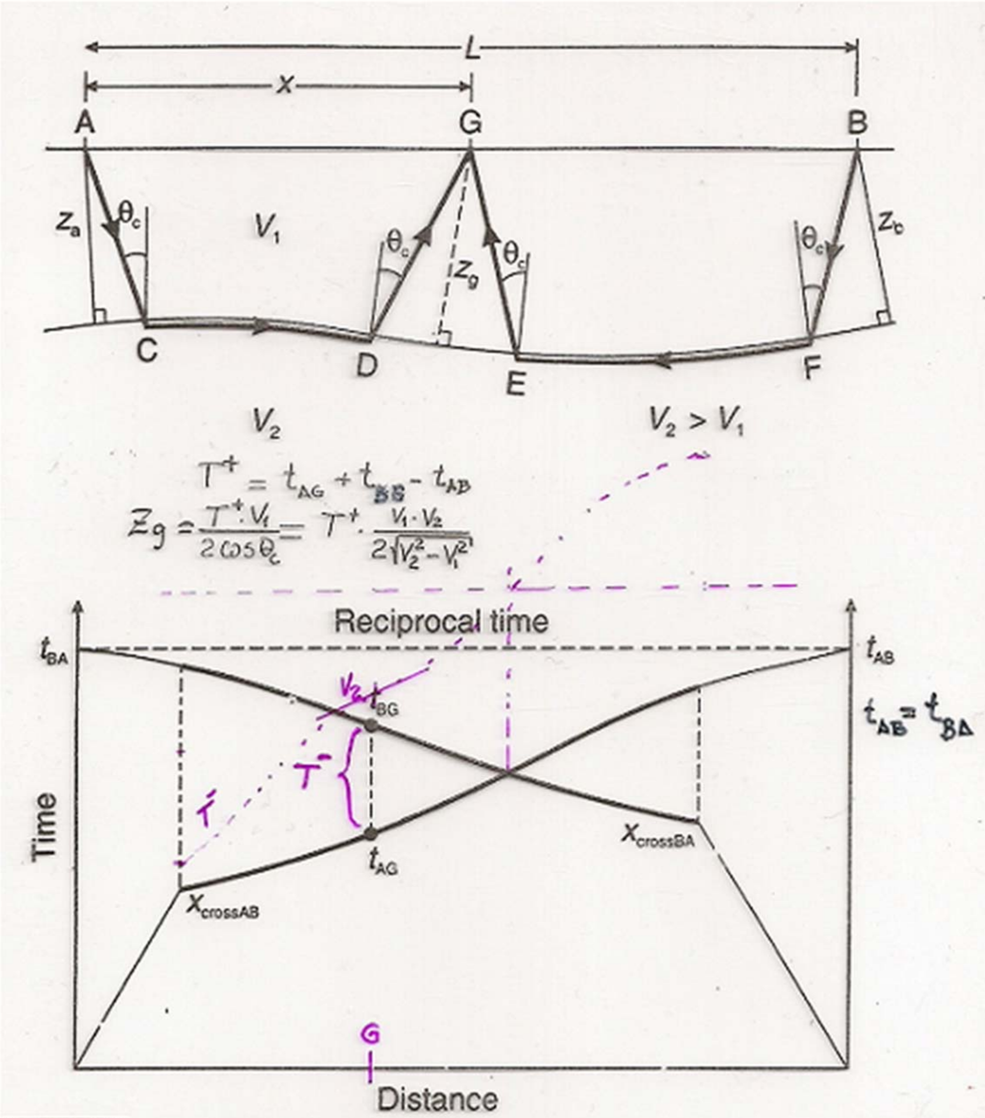
Limitaciones de la sísmica de refracción



Limitaciones de la sísmica de refracción



Determinación de la topografía del techo de la roca consolidada (bedrock)



Método de T^+ T^- (Hagedoorn)

Método de más-menos (Hagedoorn).

$T^+ = t_{AG} + t_{BG} - t_{AB} = Z_g\, 2\cos\theta_c / V_1$

$Z_g = \frac{T^+ V_1}{2\cos\theta_c} = T^+ \frac{V_1 V_2}{2\sqrt{V_2^2 - V_1^2}}$. cálculo de la profundidad

$T^- = t_{AG} - t_{BG} = \frac{x}{V_2} - \frac{L-x}{V_2} + t_{ra} - t_{rb}$

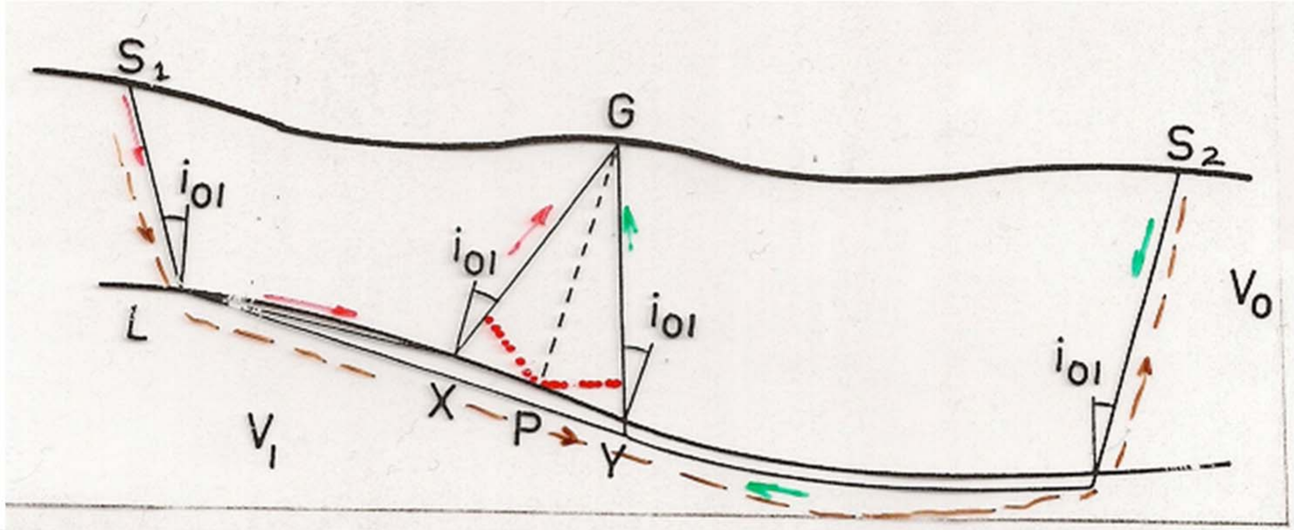
t_r: tiempo de retardo

$a = 2x - L$

(en el entorno de G) $T^- = \frac{2x-L}{V_2} + t_{ra} - t_{rb} \Rightarrow T^- = \frac{a}{V_2} + C$ cálculo de velocidad

Si grafico $T^- = f(x)$ en cada tramo puedo definir V_2 en cada tramo (T vs x)

Determinación topografía de un horizonte



$$\overline{XP} \cdot tg\, i_0 = \overline{GP}$$

$$\overline{XG} \cdot \cos i_0 = \overline{GP}$$

$$\operatorname{sen} i_0 = \frac{V_0}{V_1}$$

t_w (tiempo de profundidad en G)

$XP = XG \operatorname{sen} i_0$ $\quad XG = \frac{GP}{\cos i_0}$

DATOS

- t_{S_1G}
- t_{S_2G}
- $t_{S_1S_2}$
- V_1
- V_0

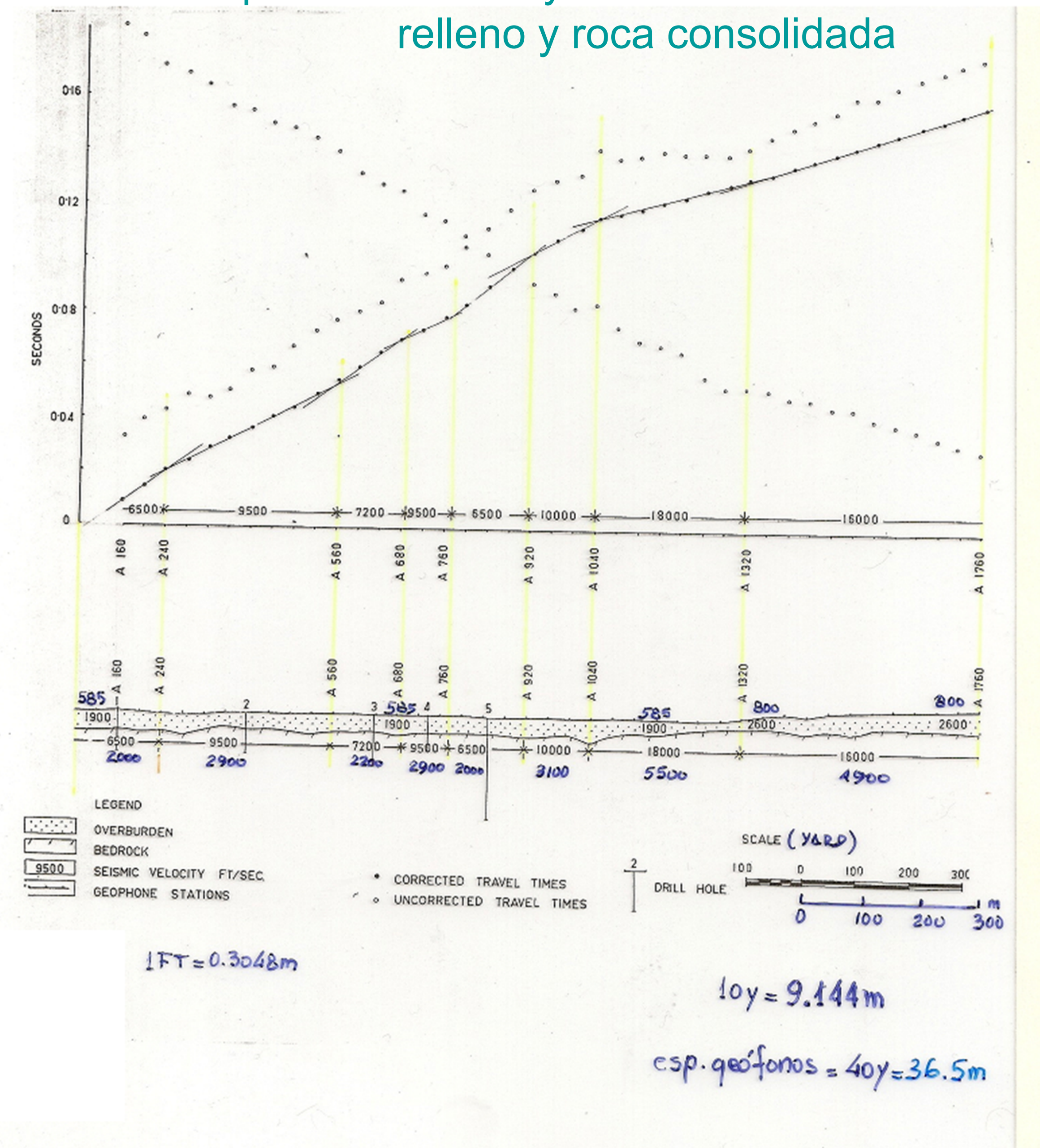
$$t_w = \frac{1}{2}\left(t_{S_1G} + t_{S_2G} - t_{S_1S_2}\right) \therefore t_w = \frac{XG}{V_0} - \frac{XP}{V_1}$$

$$\frac{XP}{V_1} = \frac{XP \operatorname{sin} i_0}{V_0}$$

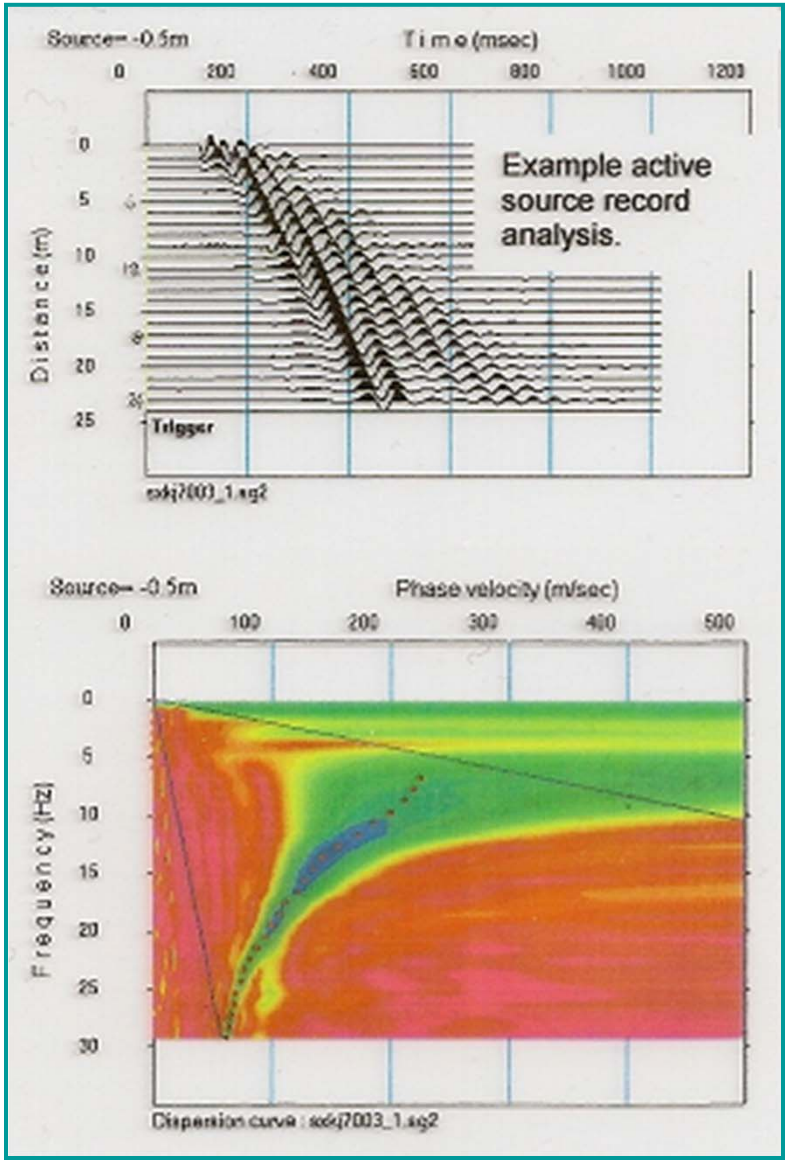
$$\overline{GP} = \frac{t_w V_0 V_1}{\left(V_1^2 - V_0^2\right)^{1/2}}$$

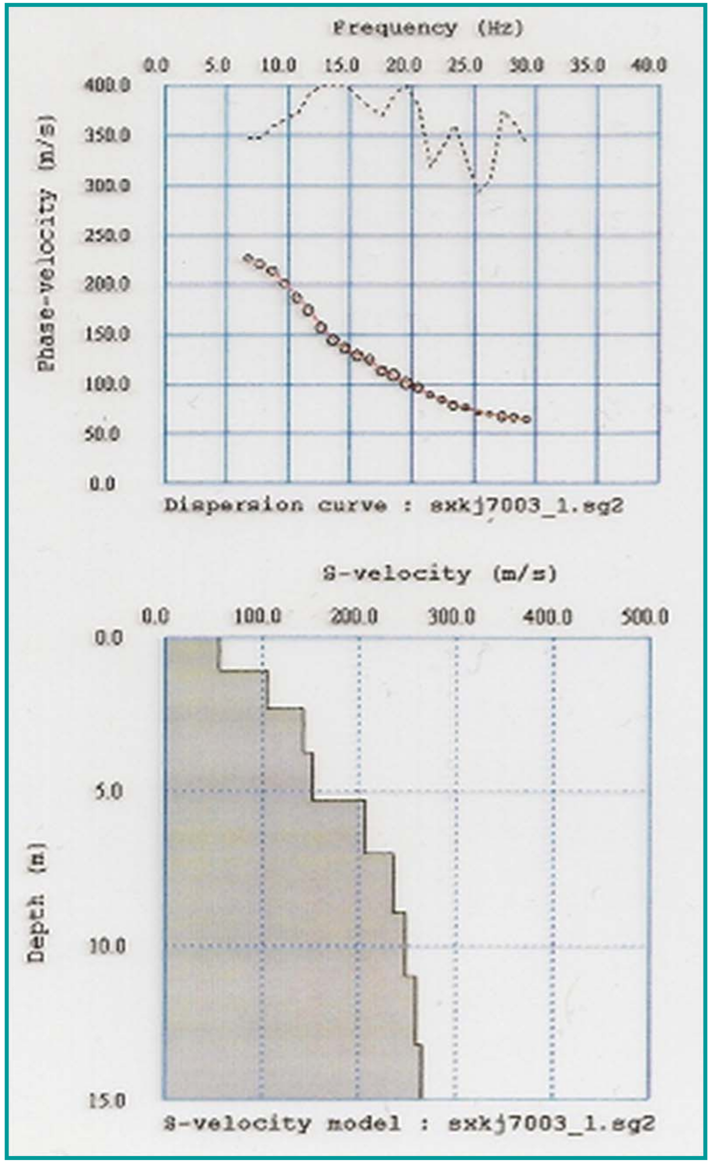
Se puede calcular el espesor o profundidad en estaciones intermedias.

Caso Histórico: Determinación de topografía de la capa consolidada y velocidades del material de relleno y roca consolidada



Determinación de un perfil 1D de las Ondas S, sobre la base del análisis espectral de las Ondas de Superficie





▸ Passive (micro-tremor) and active source surface wave data analysis

- calculates phase velocity and plots dispersion curve
- performs automated inversion to iteratively seek 1D S-wave velocity profile
- allows active and passive source results to be combined into one high-resolution velocity plot
- includes editing and QC functions, velocity modeling

▸ Determine S-wave velocity for a variety of applications

- IBC Vs30 site classification
- foundation engineering
- void detection
- in-fill and landfill investigation
- stratigraphic and lithologic studies
- deeper surveys of geologic structure

▸ Wizard-driven operation for easy, straight-forward data analysis

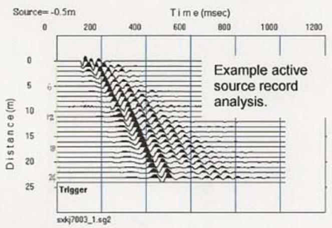
Surface waves are easy to record and loaded with information about the subsurface. With SeisImager/SW, data processing is simple, putting the answers you seek at your fingertips.

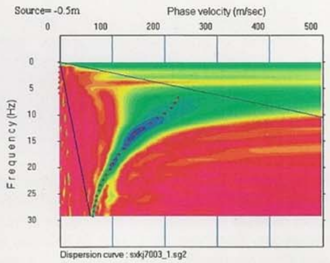
A typical dataset consists of one active source record and 20 passive or micro-tremor source records. Upon launching the software, a wizard walks you through the analysis. SeisImager/SW includes default parameters that are suitable for most cases, but are fully user-adjustable as needed.

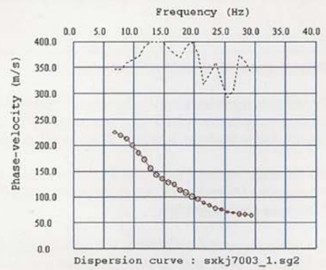
SeisImager/SW includes both active source and passive source data analysis capability. The higher frequency data from a sledgehammer source that travels through shallow depths can be combined with lower frequency data from micro-tremors that travel through greater depths. Combine the results for one high-resolution plot of S-wave velocity.

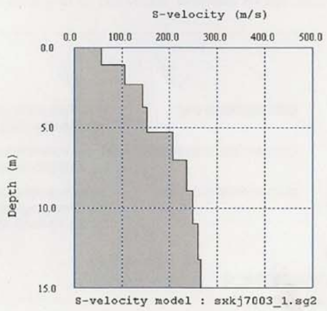
SeisImager/SW is now available for purchase separately or as an option with the Geometrics ES-3000, Geode, and StrataVisor NZ seismographs. The software comes standard with the specialized, low-priced ES-SW 16-channel seismograph package tailored for IBC Vs30 surveys.

Contact Geometrics at sales@geometrics.com for prices and to find out more about how SeisImager/SW can work for you.

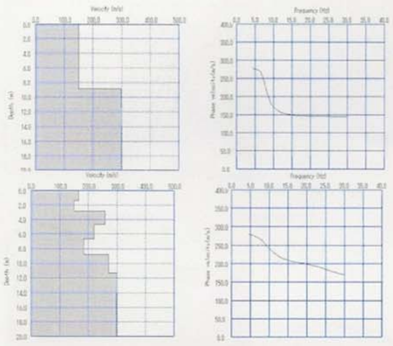








SeisImager/SW Surface Wave Analysis Software



In addition to the main functions used to determine the S-wave velocity, SeisImager/SW also allows the user to build models and examine the effects of velocity variations. Borehole data such as P-wave velocities and blow counts (N-values) can also be correlated.

SeisImager/SW Software Packages:

Demonstration version: for use on Windows PC with mouse, may be launched 15 times, capable of 1D active source Multi-channel Analysis of Surface Waves (MASW).

1D version: runs on Windows PC with mouse, capable of 1D passive Micro-tremor Array Measurements (MAM) and 1D active source MASW.

2D version: runs on Windows PC with mouse, capable of 1D passive MAM and 1D and 2D active source MASW. Note: not yet released, scheduled for late 2005.

With Geometrics seismographs, data acquisition is simple. For active source data, take one or two off-end shots with a 20-lb (9 kg) sledgehammer. In noisier environments, you can also stack multiple shots for increased signal-to-noise ratio. For passive or micro-tremor source data, manually trigger the seismograph to record 20 records of 30 seconds each.

SeisImager/SW is available for purchase separately or as an option with the ES-3000, Geode, and StrataVisor NZ seismographs. It comes standard with the specialized, low-priced ES-SW 16-channel seismograph package tailored for IBC Vs30 surveys. Please contact Geometrics, Inc. for complete details.

~\SeisImagerSW_v4_ds.doc 052005

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Tel: 86-10-6588-1126, 27, 28, 29, 30 – Fax: 86-10-6588-1162 – Email: laurel@laureltech.com.cn

Ejemplo aplicación: determinación del isopáquico de la cuenca sedimentaria, para estudios de Hidrocarburos