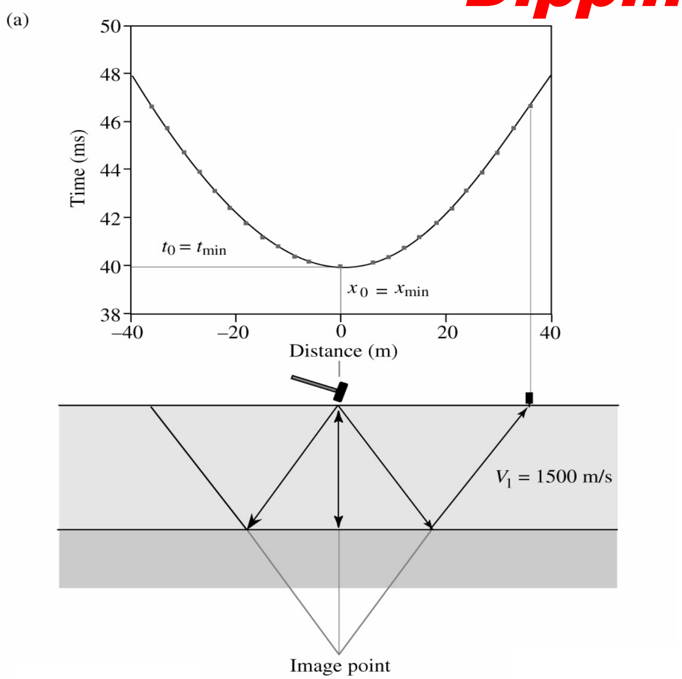
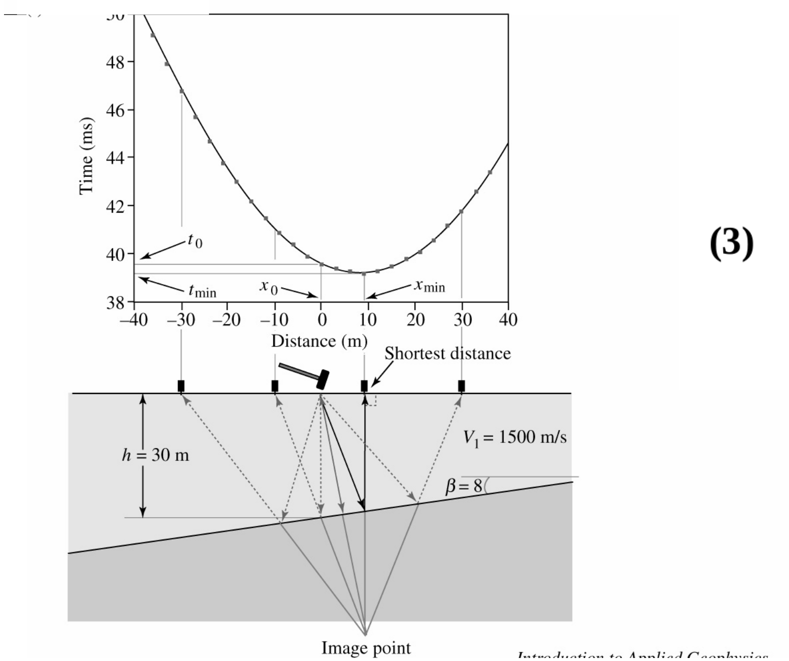
Dipping Beds: Summary Calcs





Dipping Layer t-x equation: Minimum x, t

$$\tilde{t}^2 = \tilde{x}^2 - 2\tilde{x}\sin(\alpha) + 1$$

$$\tilde{t} = \frac{t}{t_0} \quad \Leftarrow \quad t_0 = \frac{2h'}{V} \qquad \tilde{x} = \frac{x}{2h'}$$

(1)

$$\tilde{x}_{min} = \sin(\alpha)$$
$$\tilde{t}_{min} = \cos(\alpha)$$

(2)

$$x_{min} = 2h'\sin(\alpha)$$
$$t_{min} = \frac{2h'\cos(\alpha)}{V}$$
$$t_0 = \frac{2h'}{V}$$

→ **from t-x plot**

(3)

$$\frac{t_0}{t_{min}} = \cos(\alpha)$$
$$\Rightarrow \alpha = \cos^{-1}\left(\frac{t_0}{t_{min}}\right)$$

and **(4)**

$$h' = \frac{x_{min}}{2\sin(\alpha)} \qquad (a)$$
$$h = \frac{h'}{\cos(\alpha)} \qquad (b)$$

Dipping Beds: Using approach used earlier for a horiz. layer,

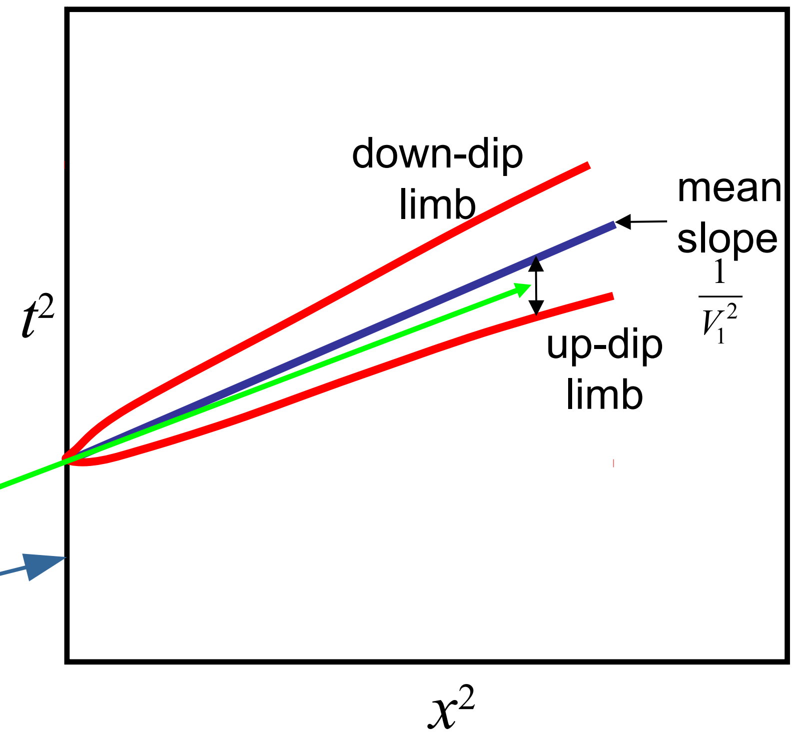
$$t = \frac{\sqrt{4h_1^2 + x^2 - 4h_1 x \sin\alpha}}{V_1} = \sqrt{\frac{4h_1^2}{V_1^2}\left(1 + \frac{x^2 - 4h_1 x \sin\alpha}{4h_1^2}\right)} = t_0\sqrt{1 + \frac{x^2 - 4h_1 x \sin\alpha}{4h_1^2}}$$

can be expanded and truncated as

$$t \doteq t_0\left(1 + \frac{x^2 - 4h_1 x \sin\alpha}{8h_1^2}\right) = t_0 + \frac{x^2 - 4h_1 x \sin\alpha}{h_1 V_1}$$

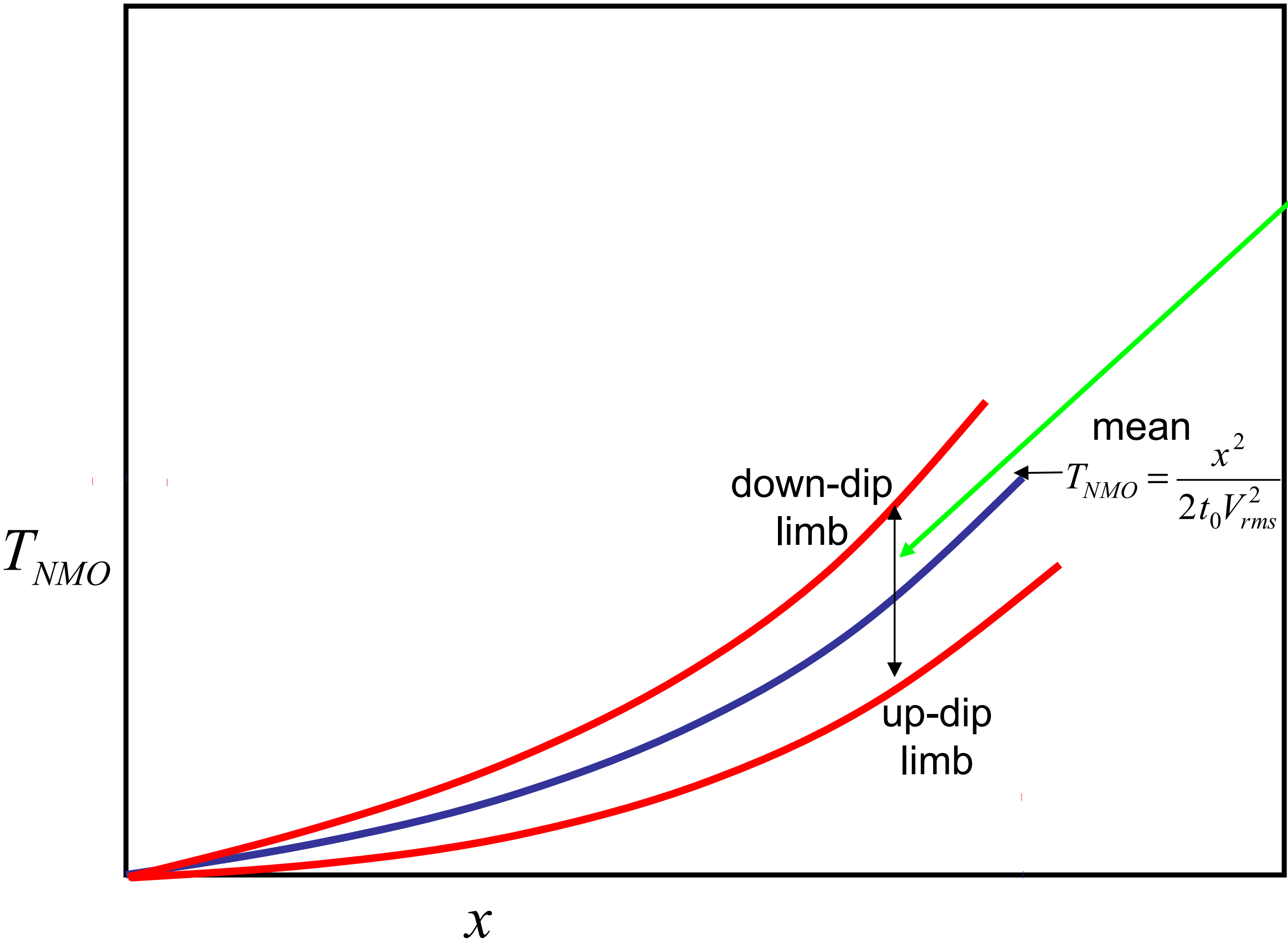
Recall the $x^2 - t^2$ plot for a dipping layer: Could average $\left(t_{+x}^2 + t_{-x}^2\right)/2$ to get a line with slope $1/V_1^2$, and the difference between the line and the limbs was related to the dip angle:

$$t^2 = \frac{x^2}{V_1^2} - \frac{4h_1 \sin\alpha}{V_1^2}x + \frac{4h_1^2}{V_1^2}$$



Binomial series approximation:

$$t \doteq t_0 + \frac{x^2 - 4h_1 x \sin\alpha}{4h_1 V_1} \qquad t_{+x} - t_{-x} \doteq \frac{-4h_1 x \sin\alpha}{4h_1 V_1} - \frac{-4h_1(-x)\sin\alpha}{4h_1 V_1} = -\frac{2x\sin\alpha}{V_1} \equiv T_{DMO}$$



We can similarly use the difference between up-dip & down-dip NMO to estimate dip via:

$$\alpha = \sin^{-1}\left(-\frac{V_1 T_{DMO}}{2x}\right)$$

Some practical considerations (a reminder!):

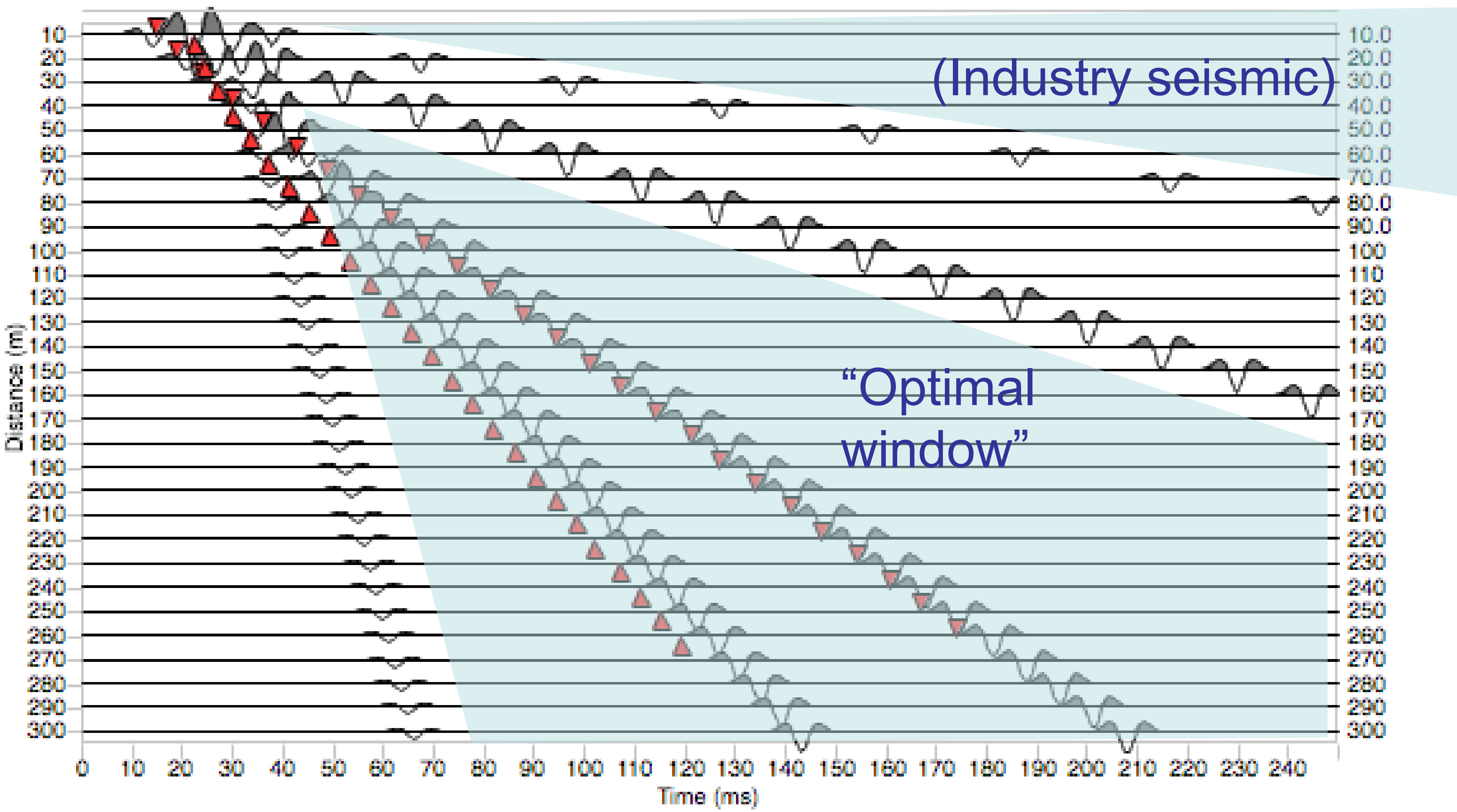
For $x^2 - t^2$ methods & Dix Equations:

- Dix equation approximation of V_{rms} is most valid for small-offset (near-vertical) rays; validity of approximations decreases with distance

For reflection seismic in general:

- NMO approximations in terms of t_0 require $x << 2h_1$ (i.e., small-offset, near-vertical rays)
- Reflections from shallow interfaces will be overwhelmed by other arrivals at small-offsets

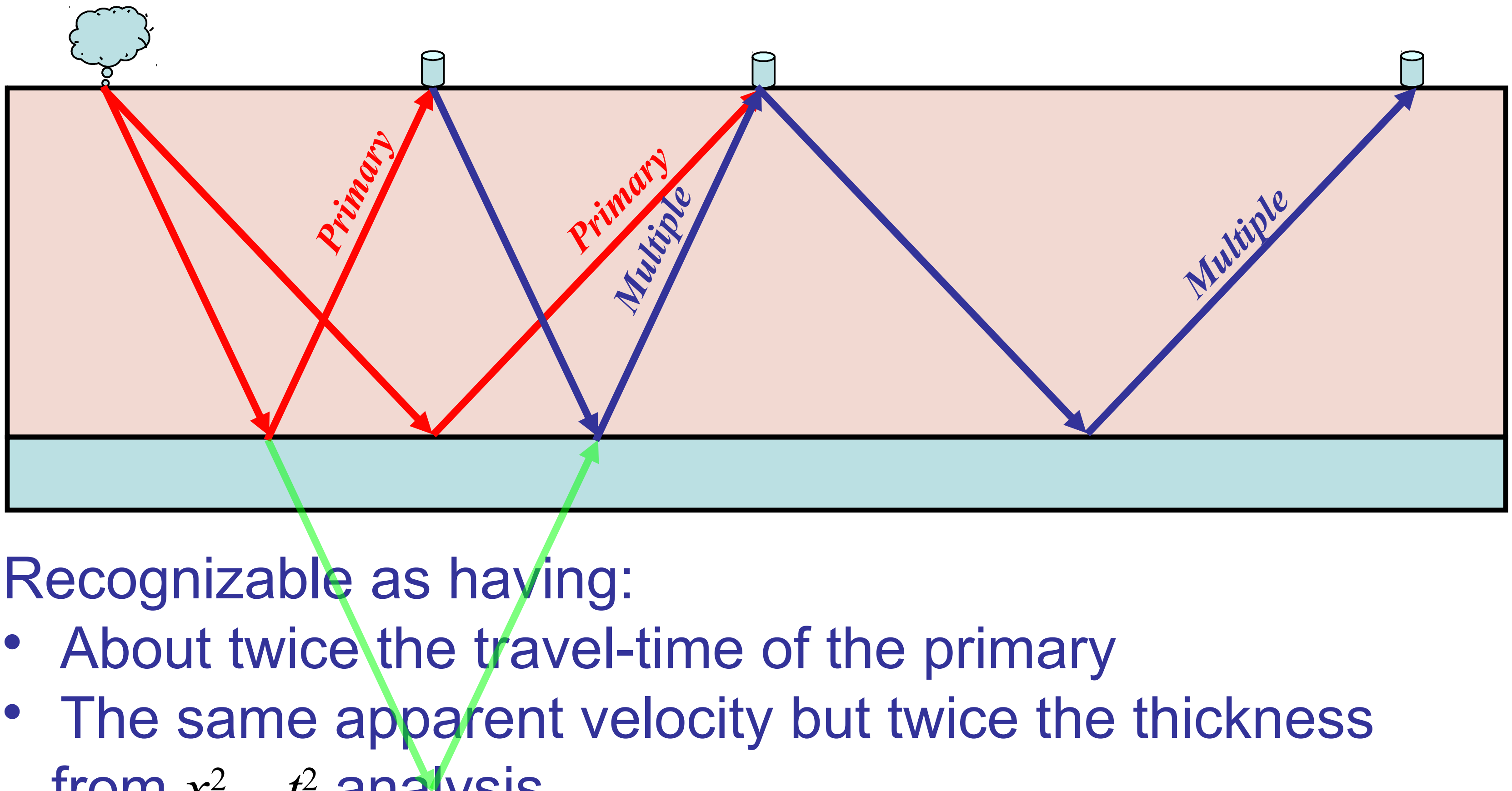
Burger refers to optimal window at distances beyond interference from low-V waves, but also must get beyond direct & refracted wave interference to observe confidently



Model traces for direct, air, ground roll, first refracted, 2 reflected waves

Practical considerations cont'd:

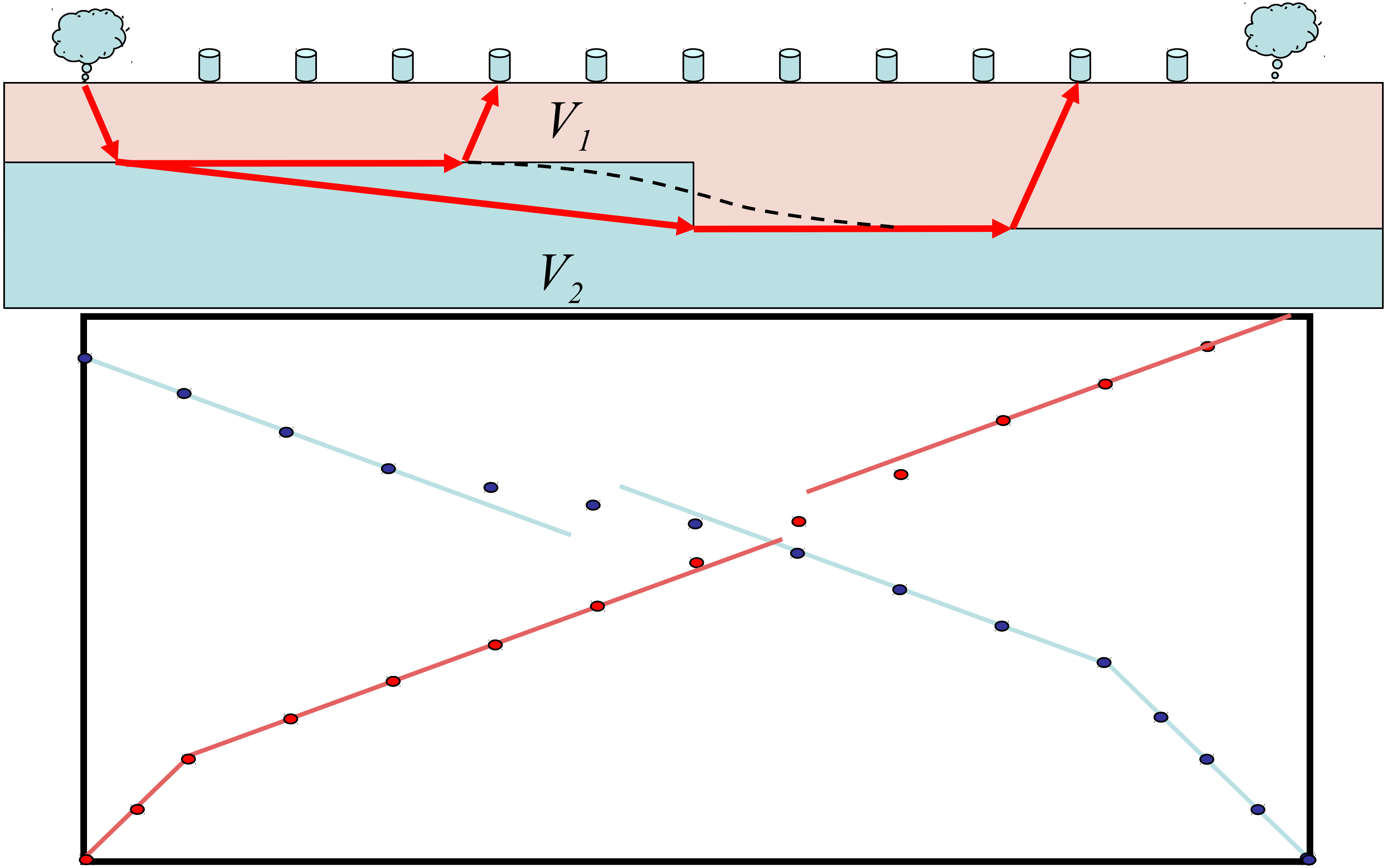
Multiples are waves that travel the two-way travel path between two interfaces more than once:



Recognizable as having:

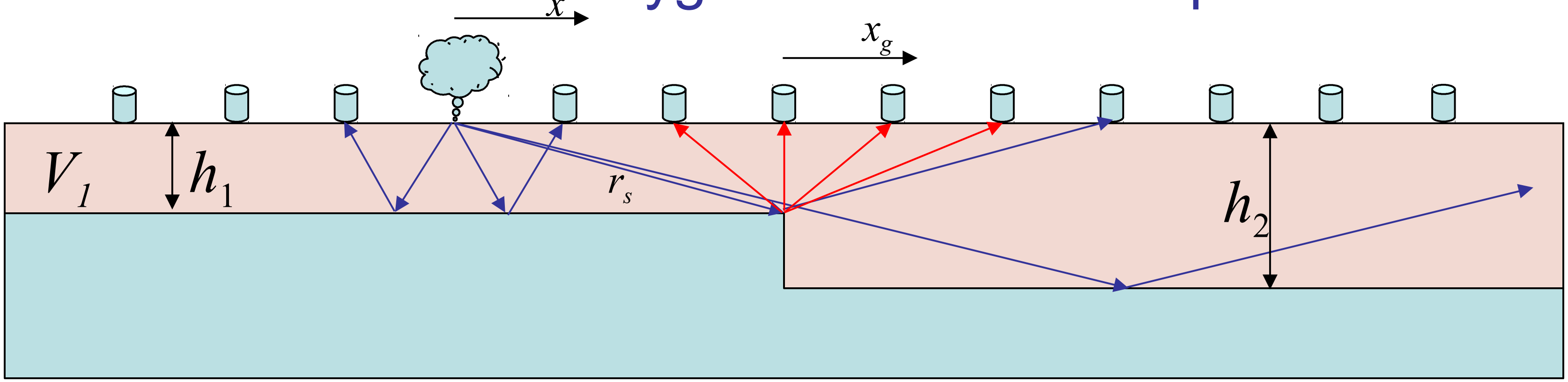
- About twice the travel-time of the primary
- The same apparent velocity but twice the thickness from $x^2 - t^2$ analysis
- Less move-out and lower amplitude than the primary

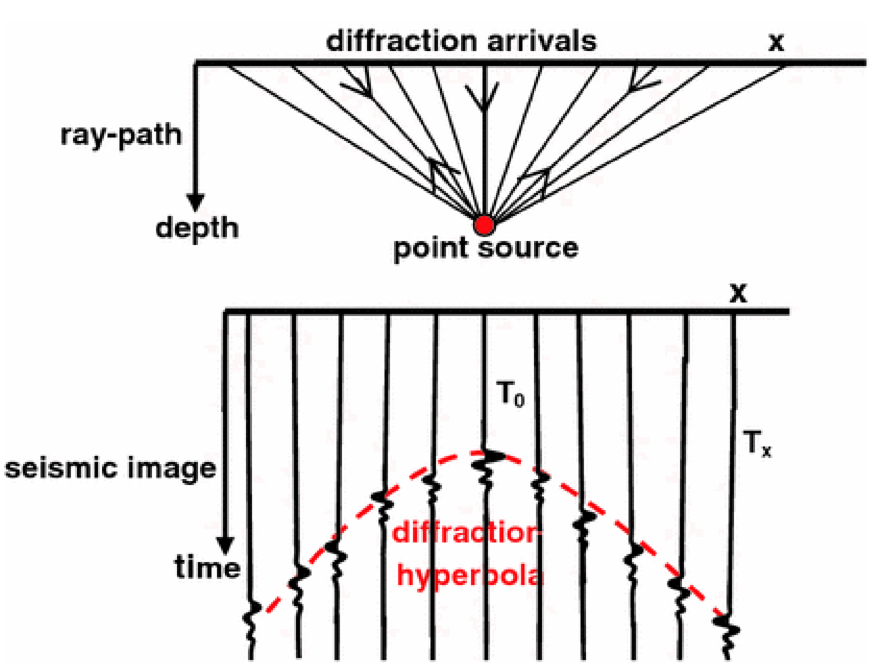
Diffractions: Recall diffractions in the refraction method:

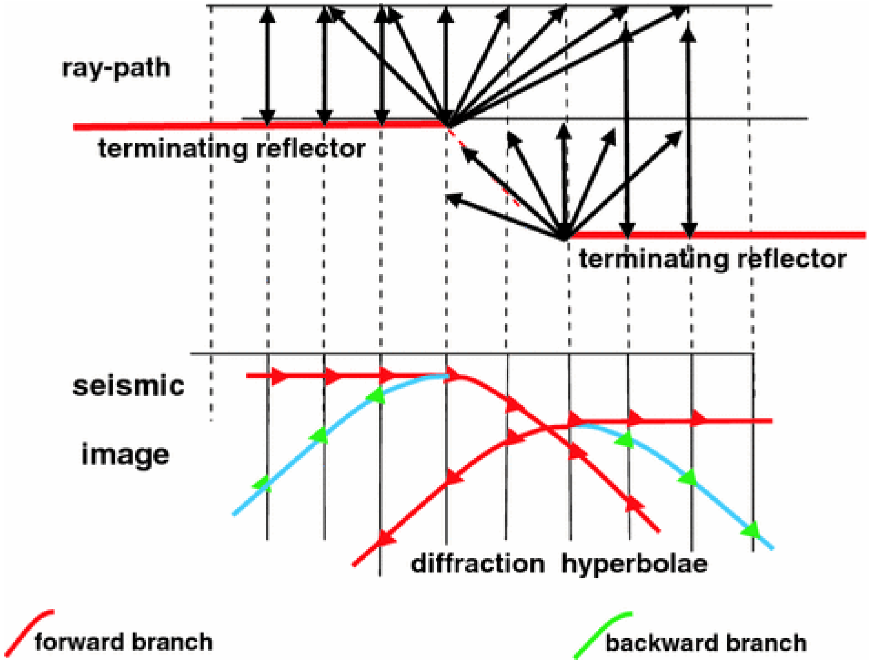


Observationally, impossible to distinguish diffracted arrival associated with a step from smooth thickness change over one wavelength (10–20 m for 100 Hz)

Diffractions: Huygens-Fresnel Principle

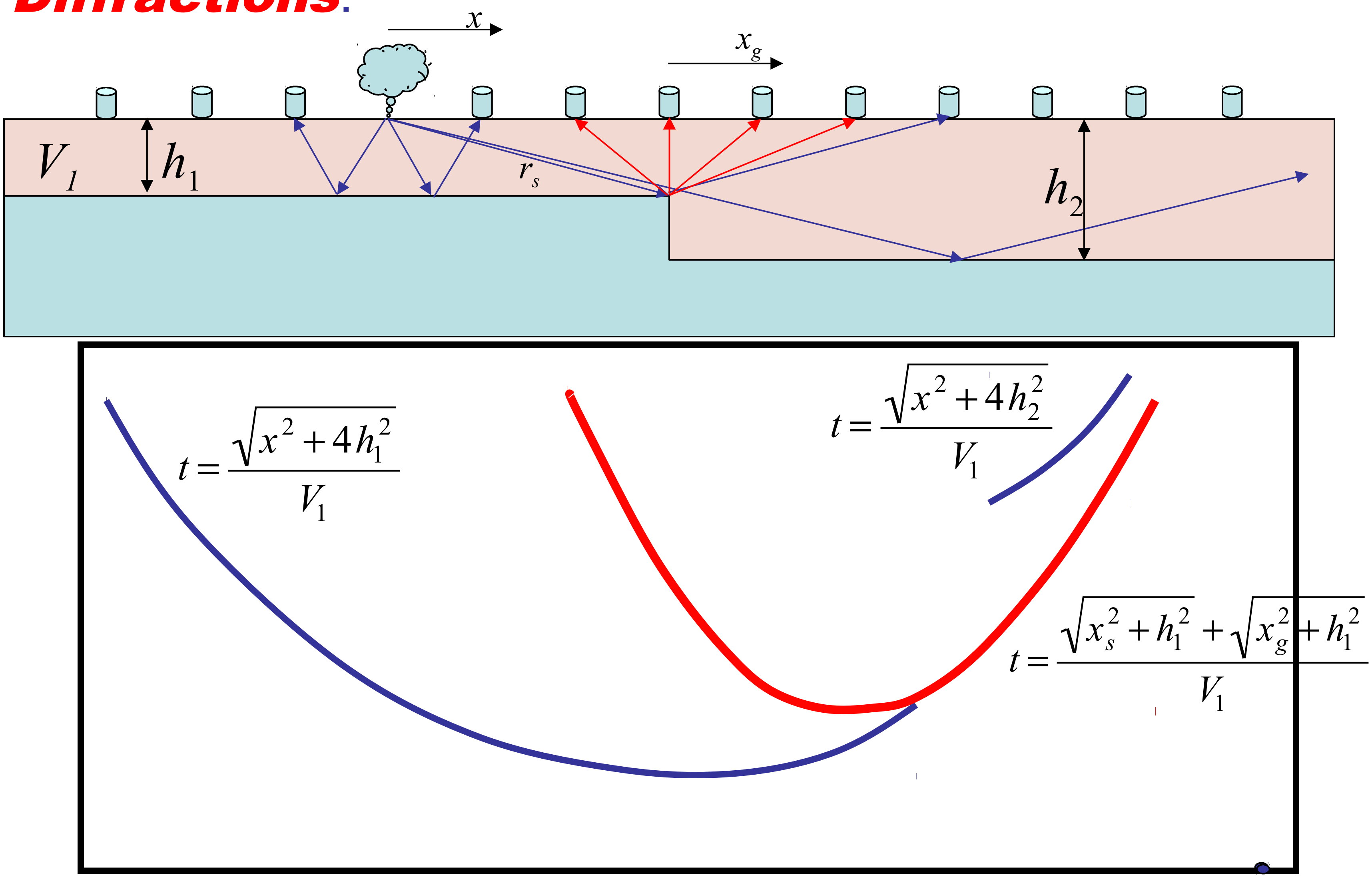






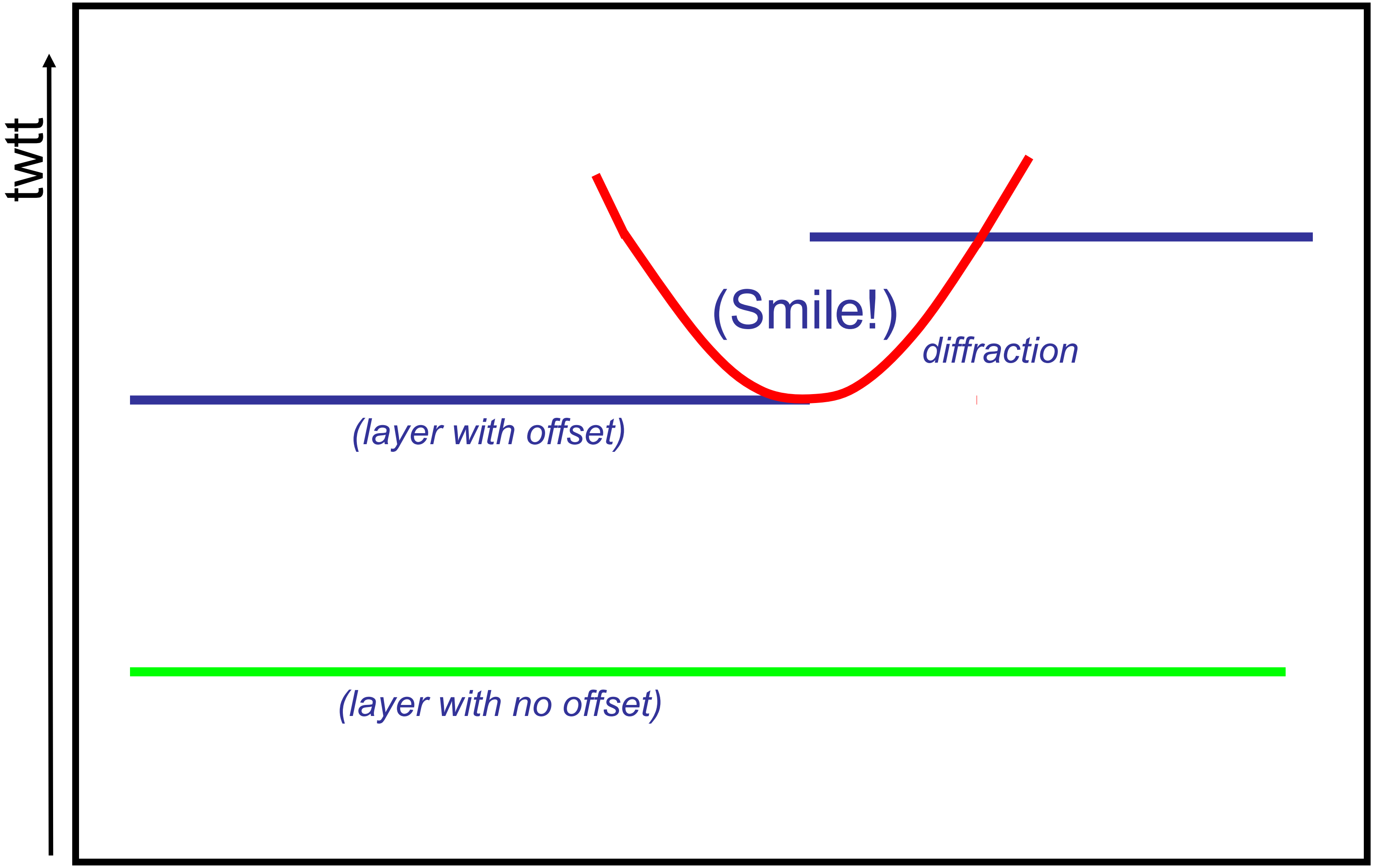
Alsadi 2017, Ch 4

Diffractions:

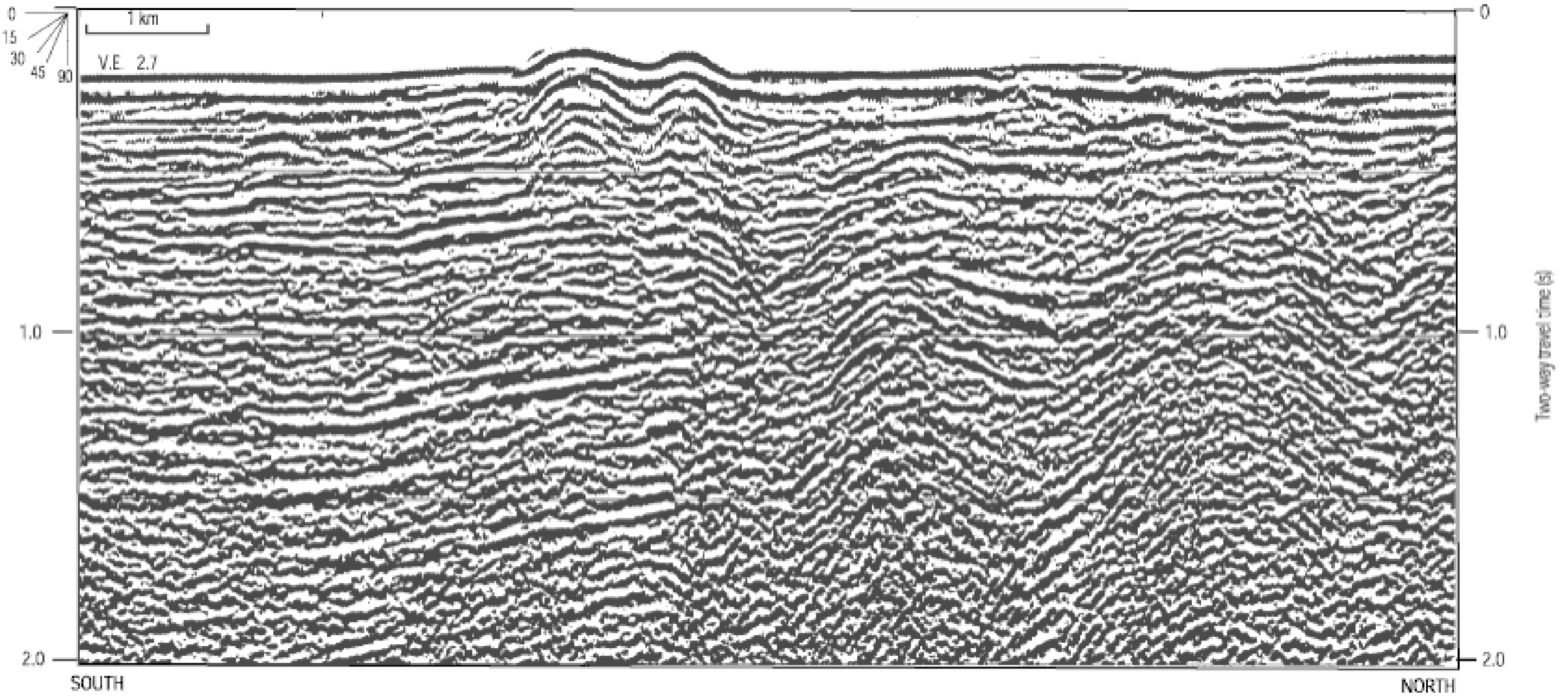


The diffraction travel time is time $t_s = r_s/V_1$ from the source to the step edge plus time t_d from step to geophone at a distance x_g from the step

Worth noting: In migration of seismic data, we "migrate" travel-times to what they would be for a zero-offset source by correcting for NMO. After correcting,



In typical seismic images we plot two-way travel-time increasing downward (to simulate depth) so “smiles” are flipped upside-down to form “frowns”



So these can be a diagnostic tool to help recognize faults, salt diapirs and other lateral changes in velocity…