METODE SEISMIK PANTUL

REFLECTION SEISMIC

Advance Exploration Geophysics Course

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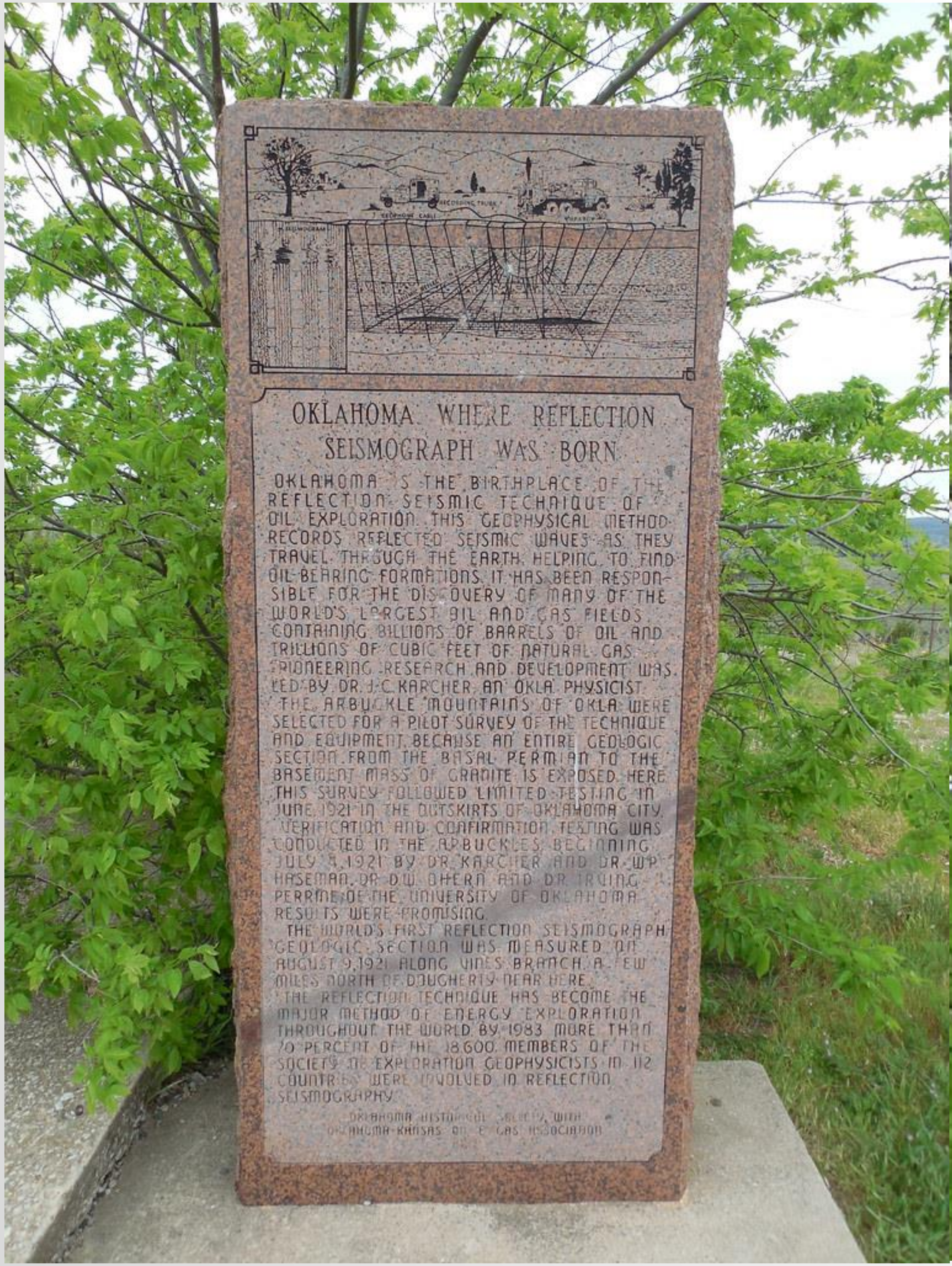
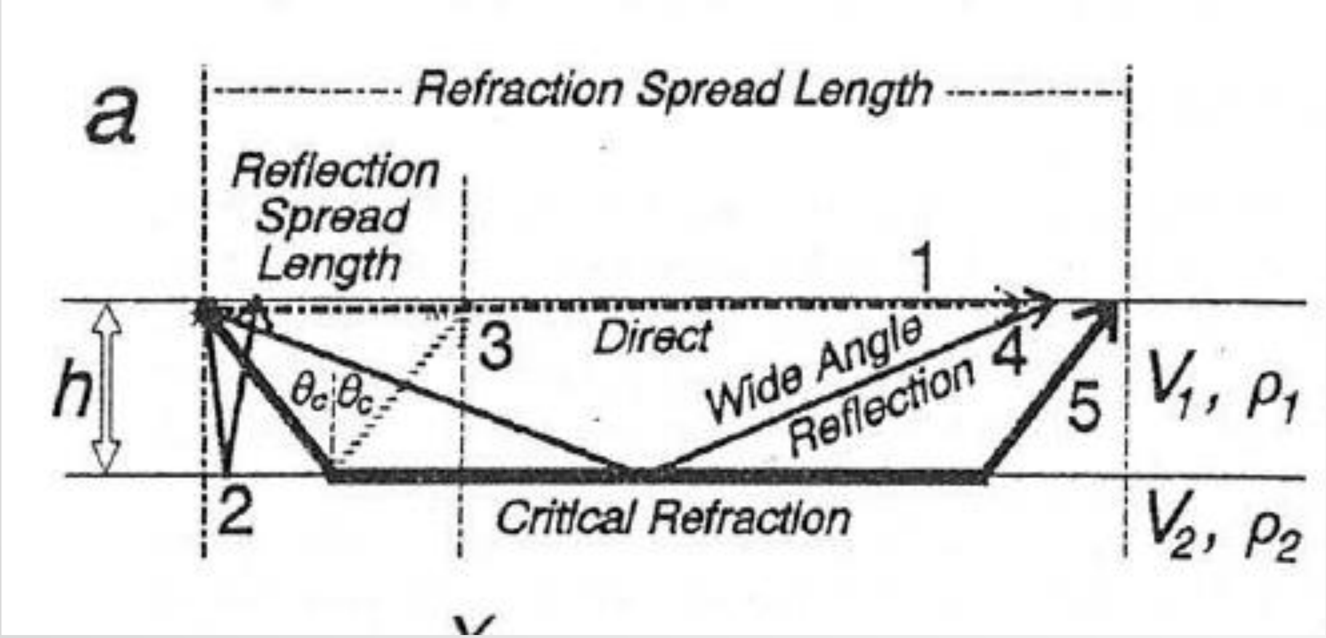


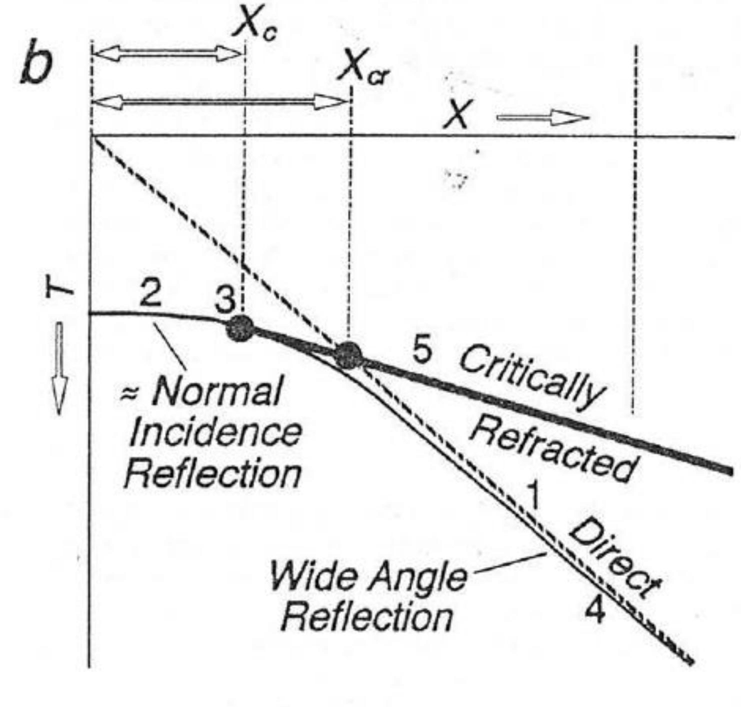
OKLAHOMA WHERE REFLECTION
SEISMOGRAPH WAS BORN
OKLAHOMA IS THE BIRTHPLACE OF THE REFLECTION SEISMIC TECHAIQUE OF OIL EXPLORATION. THIS GEOPHYSICAL METHOD RECORDS REFLECTED SEISMIC WAVES AS THEY TRAVEL THROUGH THE EARTH, HELPING TO FIND OIL-BEARING FORMATIONS. IT HAS BEEN RESPONSIBLE FOR THE DISCOVERY OF MANY OF THE WORLD'S LARGEST OIL AND GAS FIELDS, CONTAINING BILLIONS OF BARRELS OF OIL AND TRILLIONS OF CUBIC FEET OF NATURAL GAS. PIONEERING RESEARCH AND DEVELOPMENT WAS LED BY DR. J.C. KARCHER, AN OKLA. PHYSICIST.
THE ARBUCKLE MOUNTAINS OF OKLA. WERE SELECTED FOR A PILOT SURVEY OF THE TECHNIQUE AND EQUIPMENT, BECAUSE AN ENTIRE GEOLOGIC SECTION FROM THE BASAL PERMIAN TO THE BASEMENT MASS OF GRANITE IS EXPOSED HERE. THIS SURVEY FOLLOWED LIMITED TESTING IN JUNE 1921 IN THE OUTSKIRTS OF OKLAHOMA CITY. VERIFICATION AND CONFIRMATION TESTING WAS CONDUCTED IN THE ARBUCKLES BEGINNING JULY 4, 1921 BY DR. KARCHER AND DR. W.P. HASEMAN, DR. D.W. OHERN AND DR. IRVING PERRINE OF THE UNIVERSITY OF OKLAHOMA. RESULTS WERE PROMISING.
THE WORLD'S FIRST REFLECTION SEISMOGRAPH GEOLOGIC SECTION WAS MEASURED ON AUGUST 9, 1921 ALONG VINES BRANCH, A FEW MILES NORTH OF DOUGHERTY NEAR HERE.
THE REFLECTION TECHNIQUE HAS BECOME THE MAJOR METHOD OF ENERGY EXPLORATION THROUGHOUT THE WORLD. BY 1983 MORE THAN 70 PERCENT OF THE 18,600 MEMBERS OF THE SOCIETY OF EXPLORATION GEOPHYSICISTS IN 112 COUNTRIES WERE INVOLVED IN REFLECTION SEISMOGRAPHY.

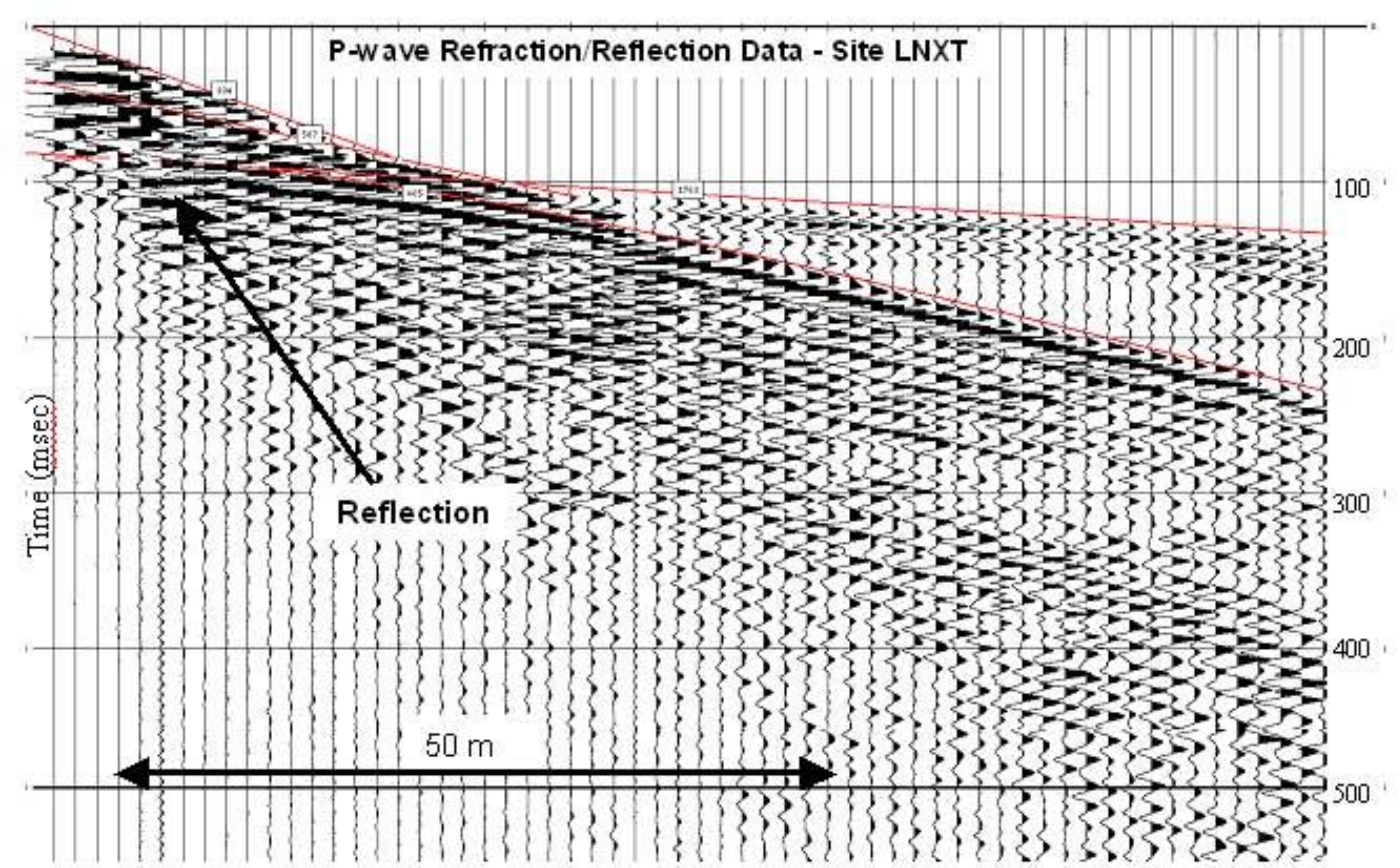
RECORDING TRUCK
OKLAHOMA WHERE REFLECTION
SEISMOGRAPH WAS BORN
OKLAHOMA IS THE BIRTHPLACE OF THE REFLECTION SEISMIC TECHAIQUE OF OIL EXPLORATION. THIS GEOPHYSICAL METHOD RECORDS REFLECTED SEISMIC WAVES AS THEY TRAVEL THROUGH THE EARTH, HELPING TO FIND OIL-BEARING FORMATIONS. IT HAS BEEN RESPONSIBLE FOR THE DISCOVERY OF MANY OF THE WORLD'S LARGEST OIL AND GAS FIELDS.

INTRODUCTION

- The seismic reflection was developed in 1920s and 30s as a tool for oil and gas exploration in sedimentary basin.
- In 1970 this method is improved in a very sophisticated level
- Seismic reflection and refraction differs in geometries and type of problem they can resolve





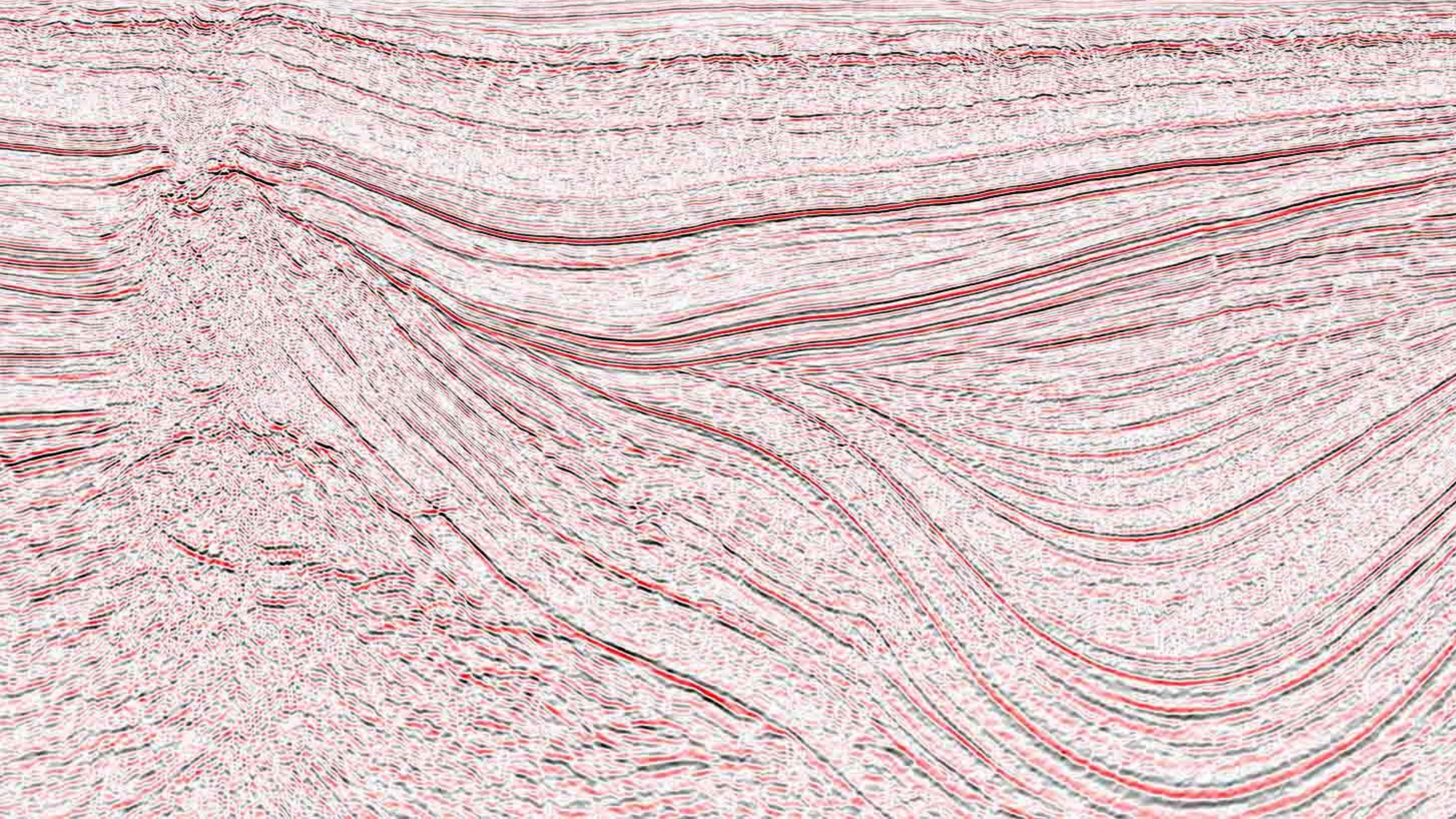


P-wave Refraction/Reflection Data - Site LNXT
Time (msec)
100
200
300
400
500
Reflection
50 m

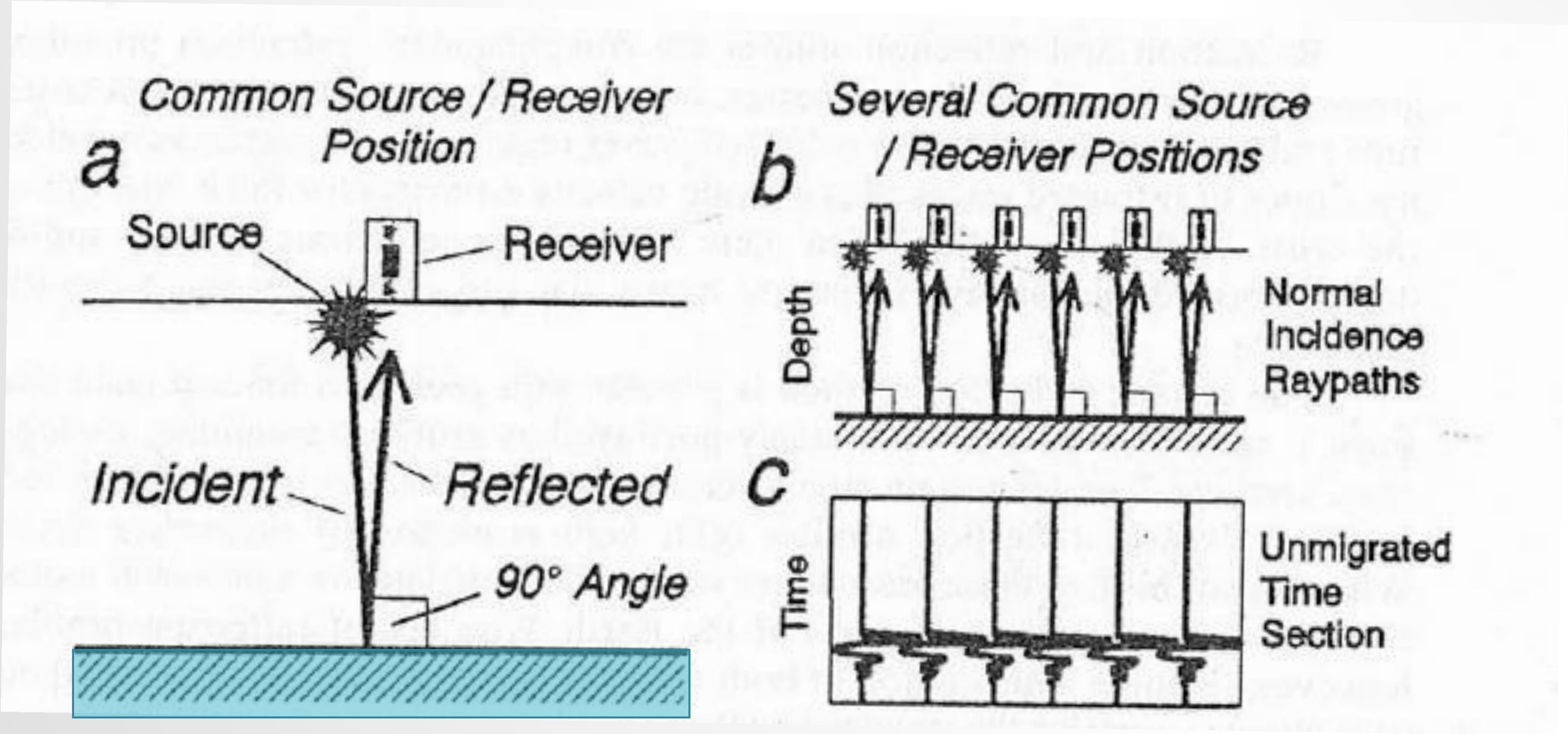
INTRODUCTION

- The seismic reflection method is popular with geologists for

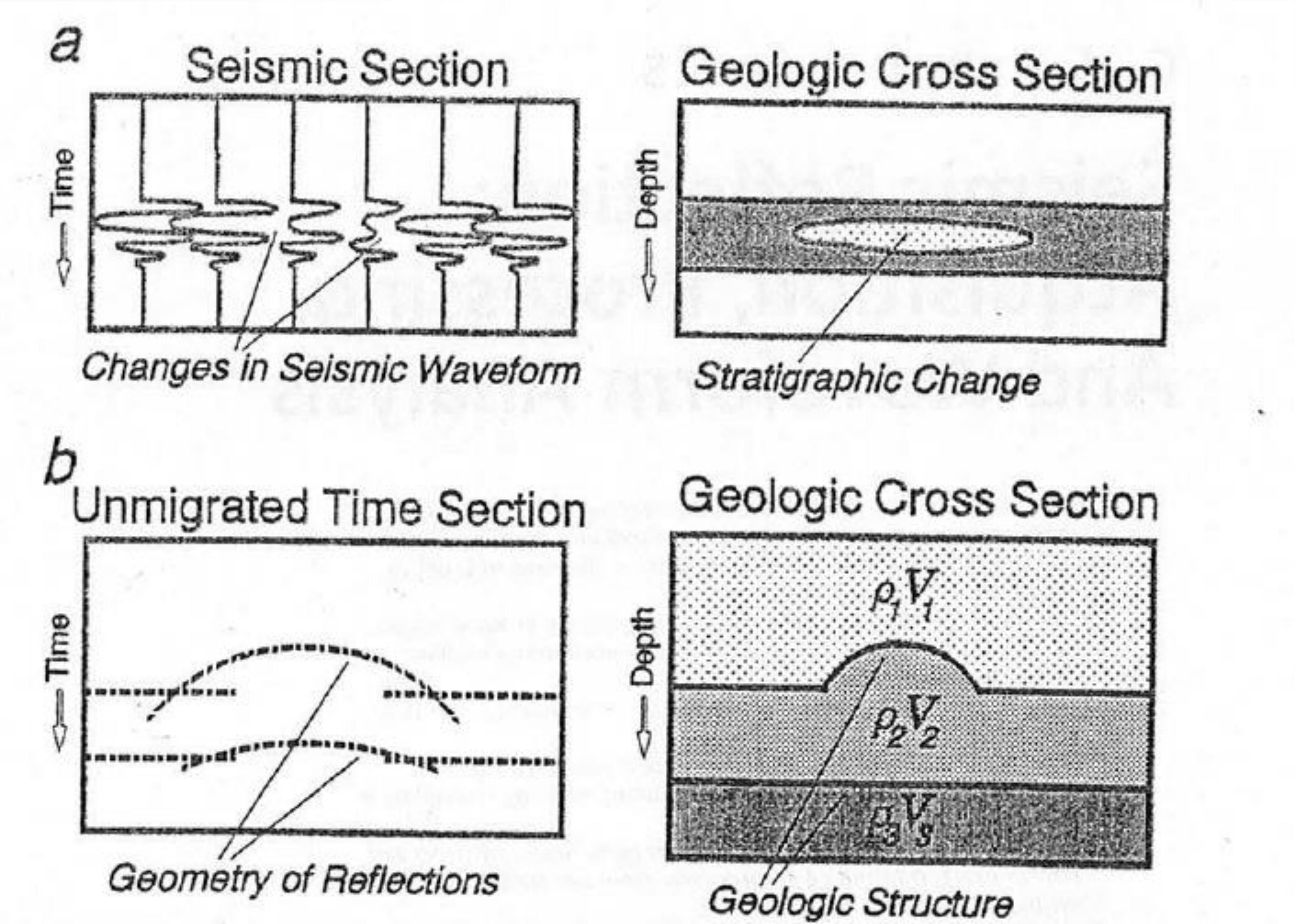
1. Reflection data commonly portrayed as profiles resembling subsurface geologic cross sections
2. Under acertain circumstances (flat-lying strata in sedimentary basins), reflection profiles offer high resolution of subsurface detail.



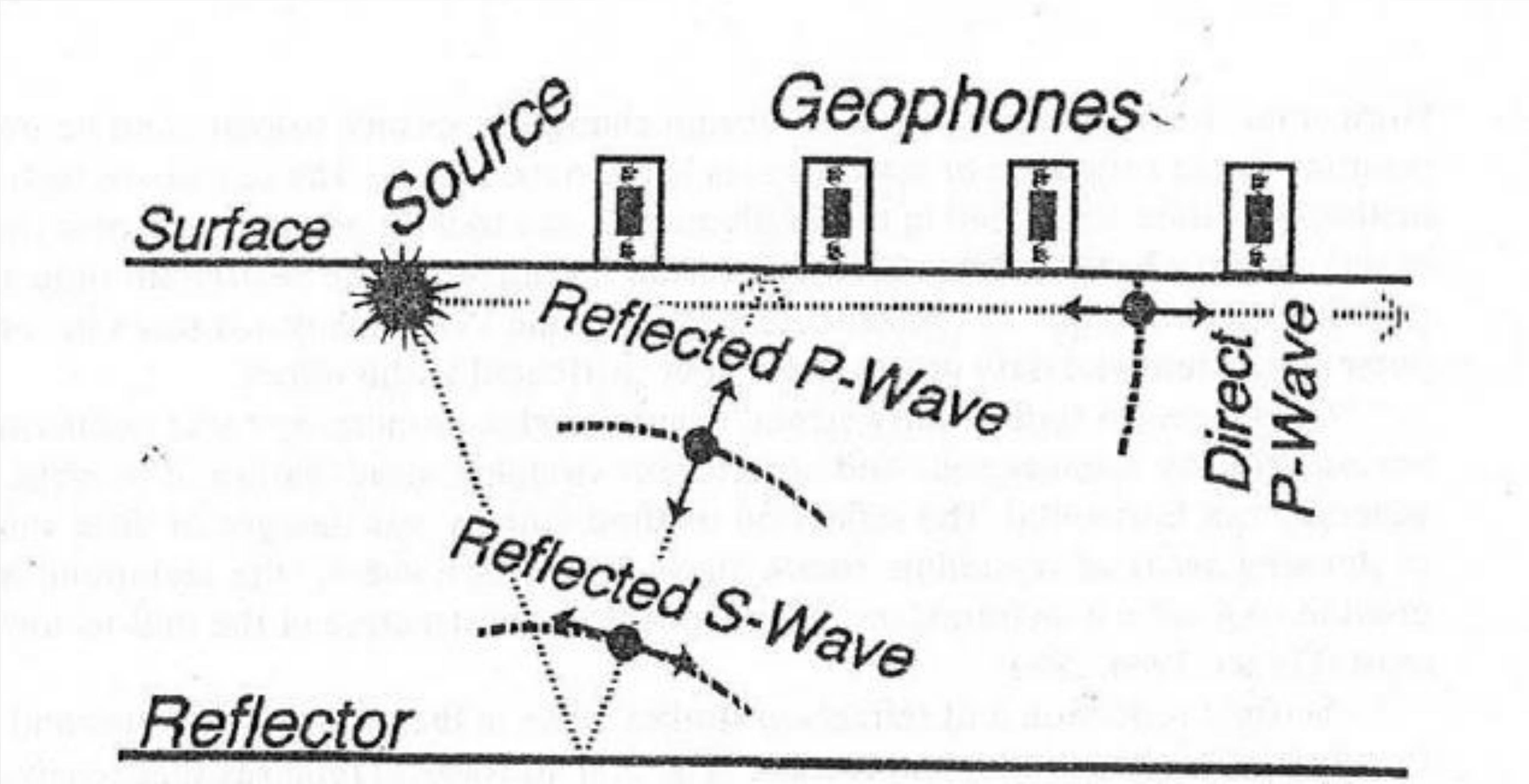
ACQUISITION



COMMON PROBLEM IN REFL. SEISMIC

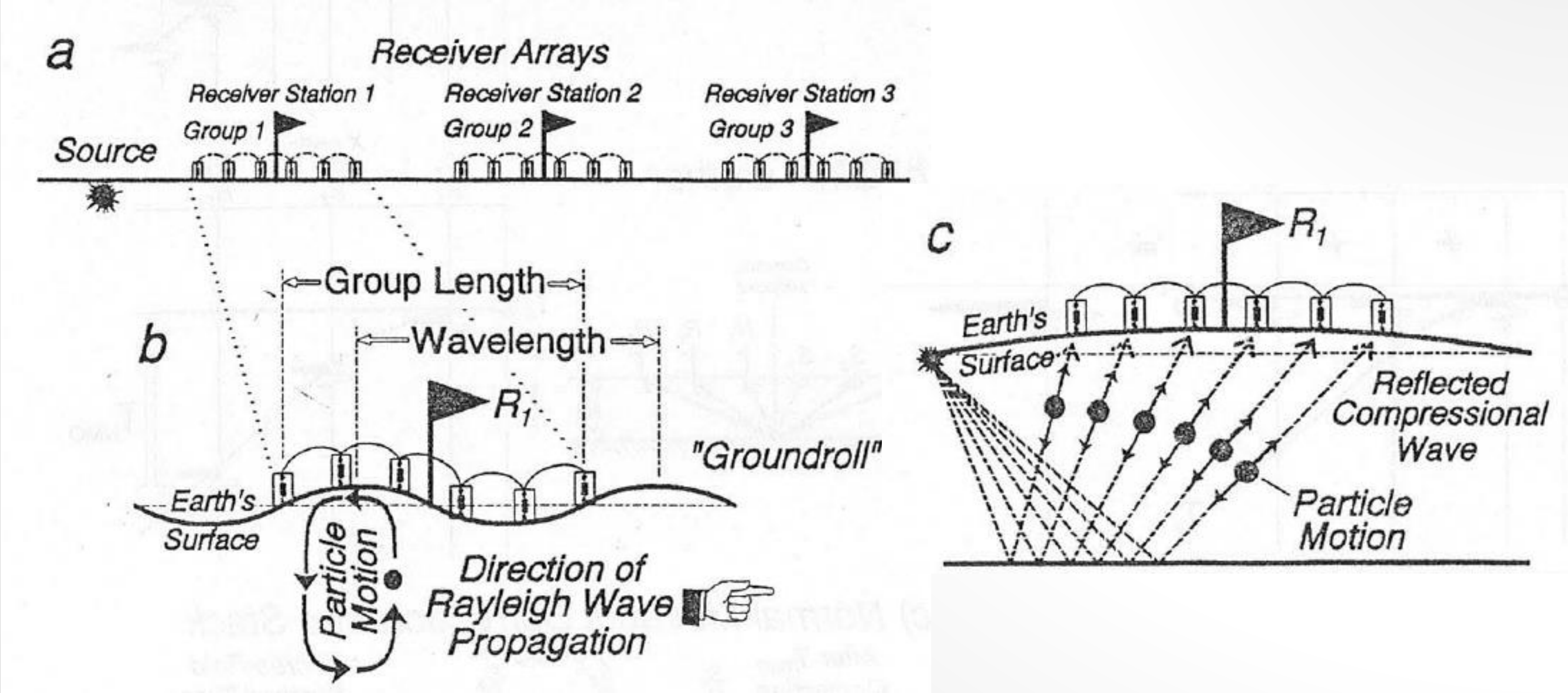


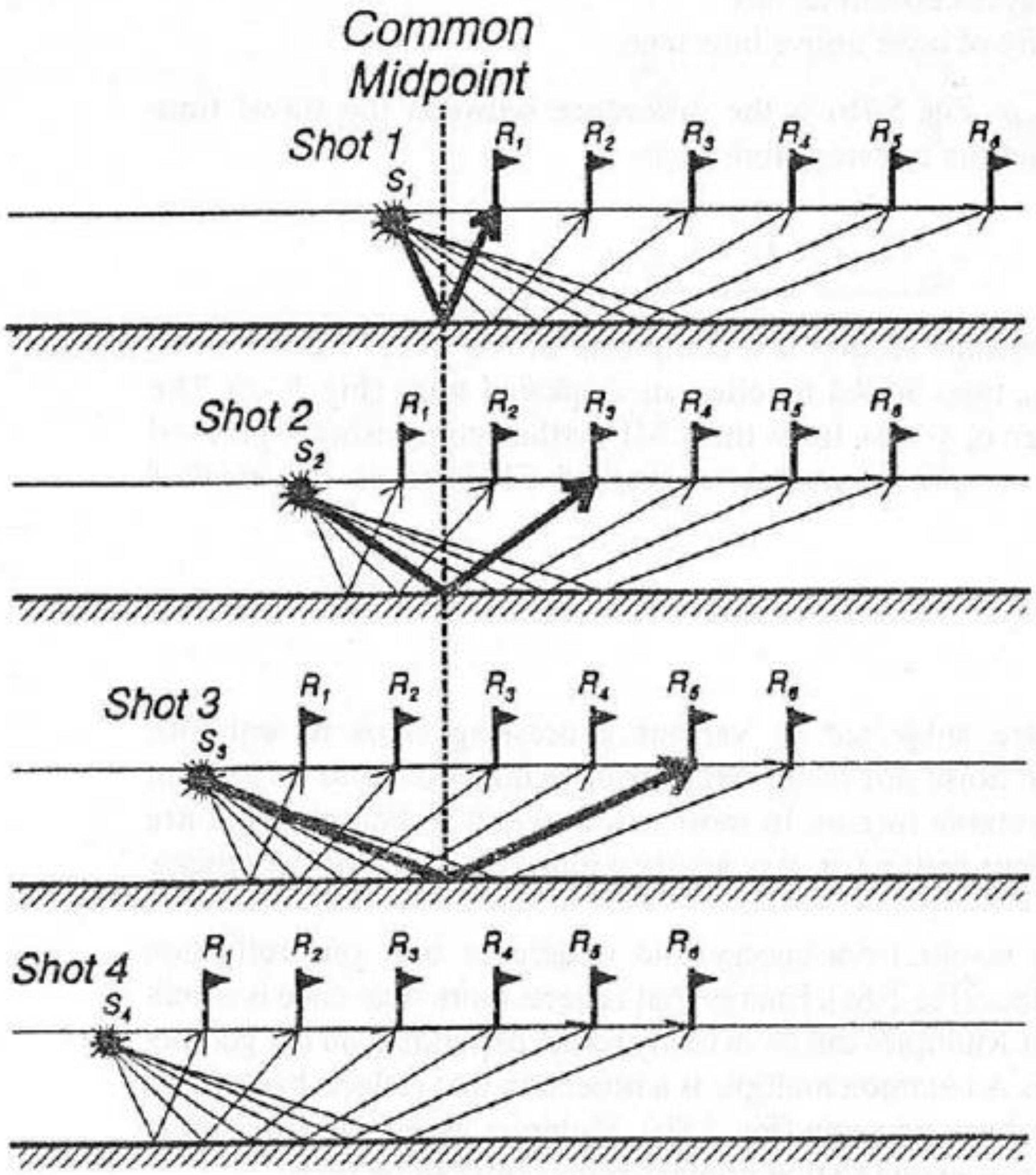
REFLECTION METHOD



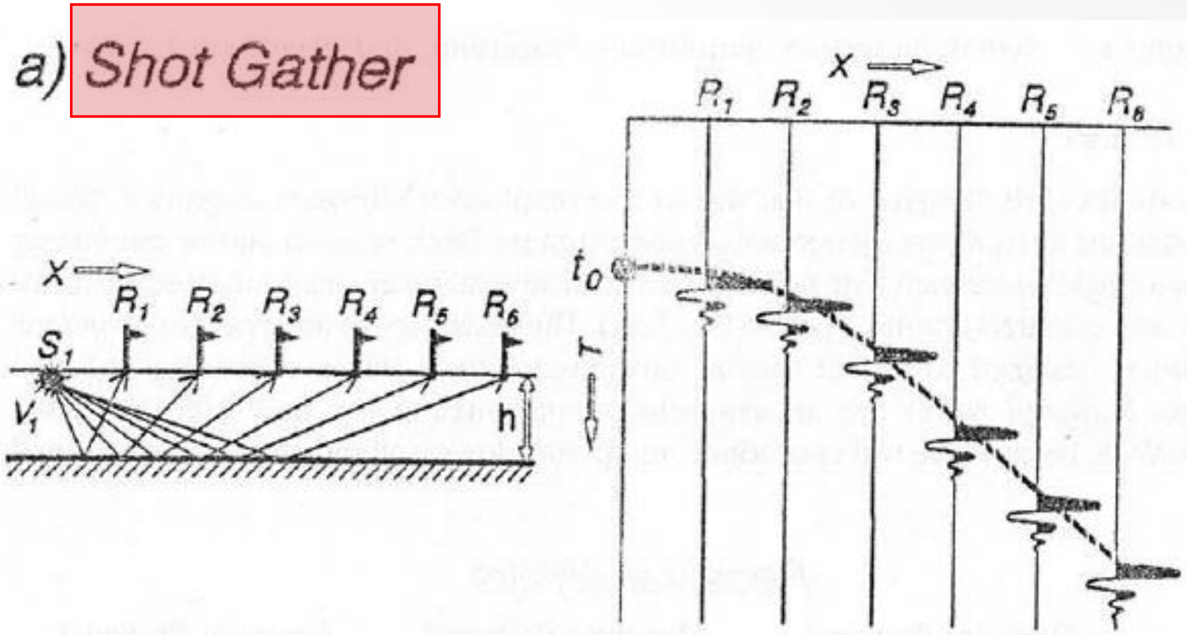
Reflected P-wave enhanced more than other arrivals. Why?

RECEIVER ARRAY





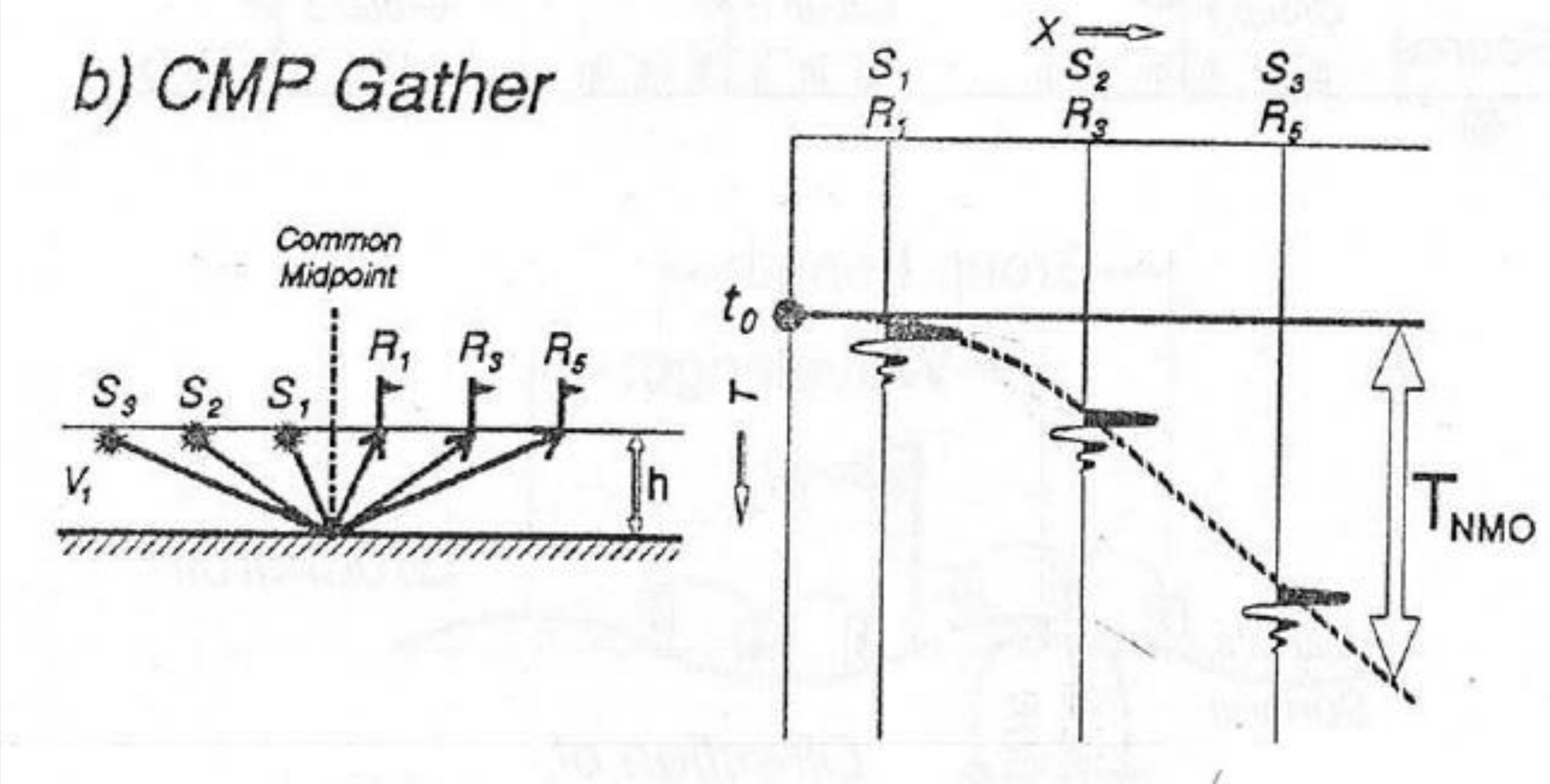
COMMON MID POINT METHOD



Each record of 6 seismic traces is known as SHOT GATHER

CMP OR CDP GATHER

- A display of traces corresponding to reflections around a common midpoint, plotted side-by-side according to horizontal distance (X) from each source, is known as CMP or CDP gather



Travel time

$$T_f = \sqrt{t_0^2 + \frac{X^2}{V_1^2}}$$

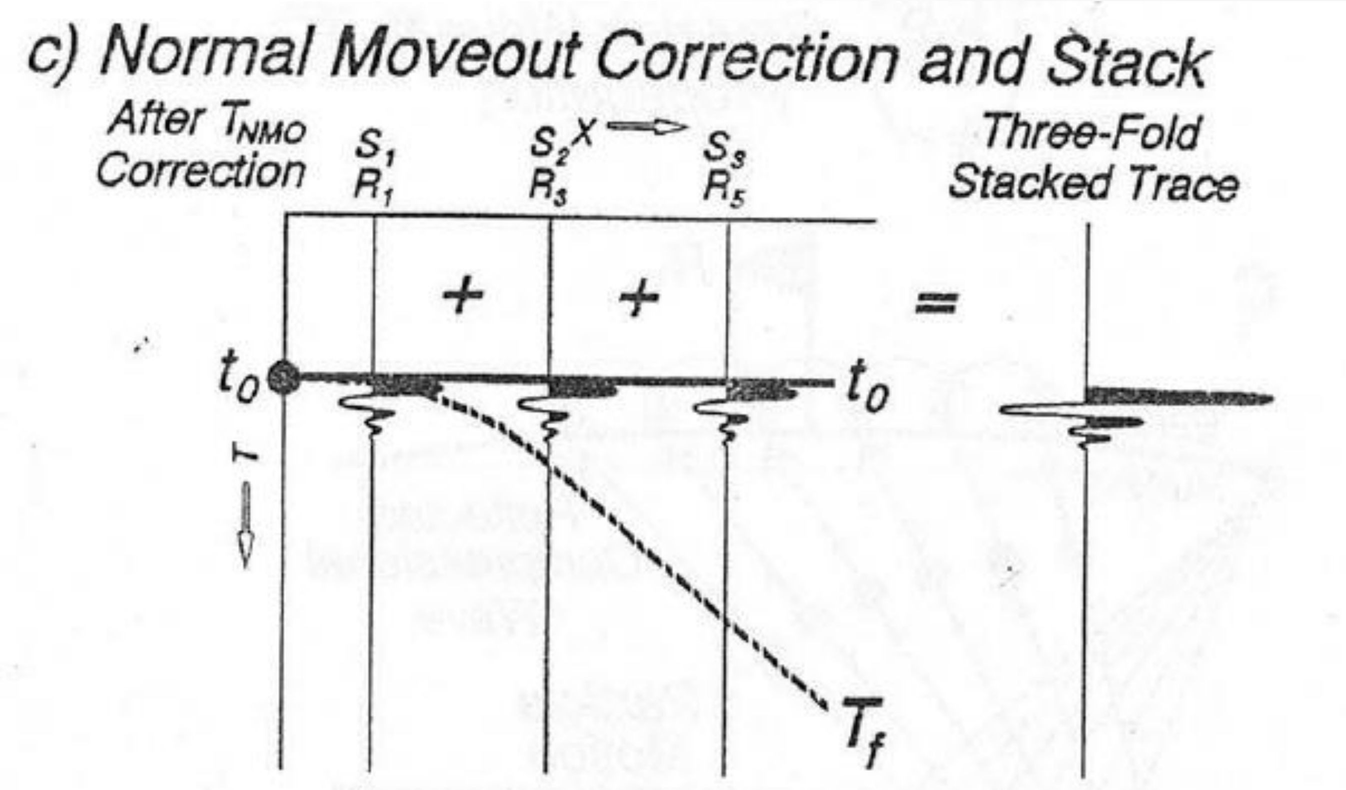
T-axis intercept

$$t_0 = \frac{2h}{V_1}$$

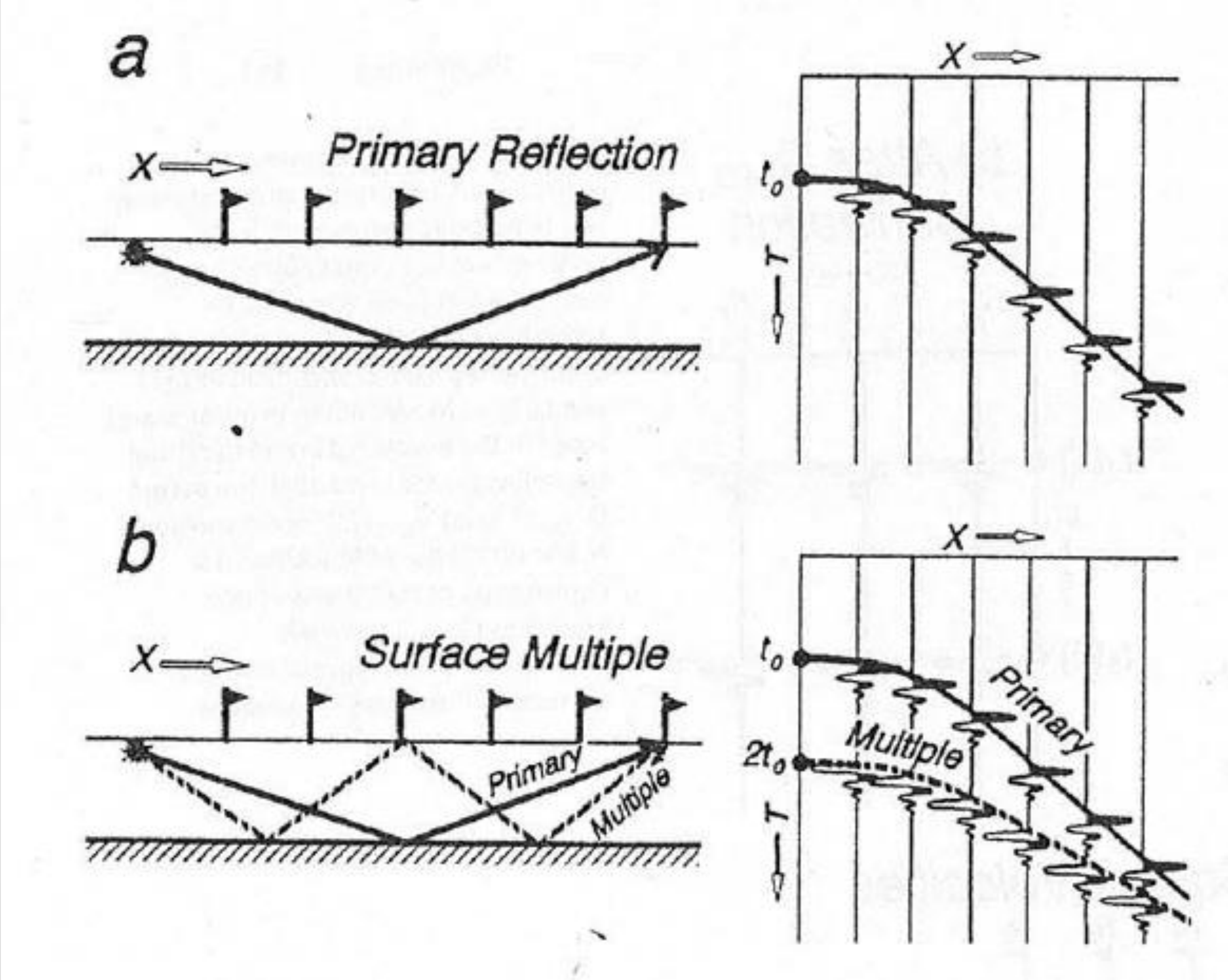
$$T_{NMO} = T_f - t_0$$

STACKED TRACE

- A single trace on seismic section is a composite of the traces from a CMP gather, corrected from T_{NMO}, then added together as a **stacked trace**
- **The fold of stack** is the number of traces from the CMP gather comprising a stacked trace. A resulting profile, comprising numerous stacked CMP traces **is STACKED SEISMIC SECTION**



SURFACE MULTIPLE



Primary reflection results from energy from only one reflection before returning to the surface.

Energy from more than one reflection is multiple reflection

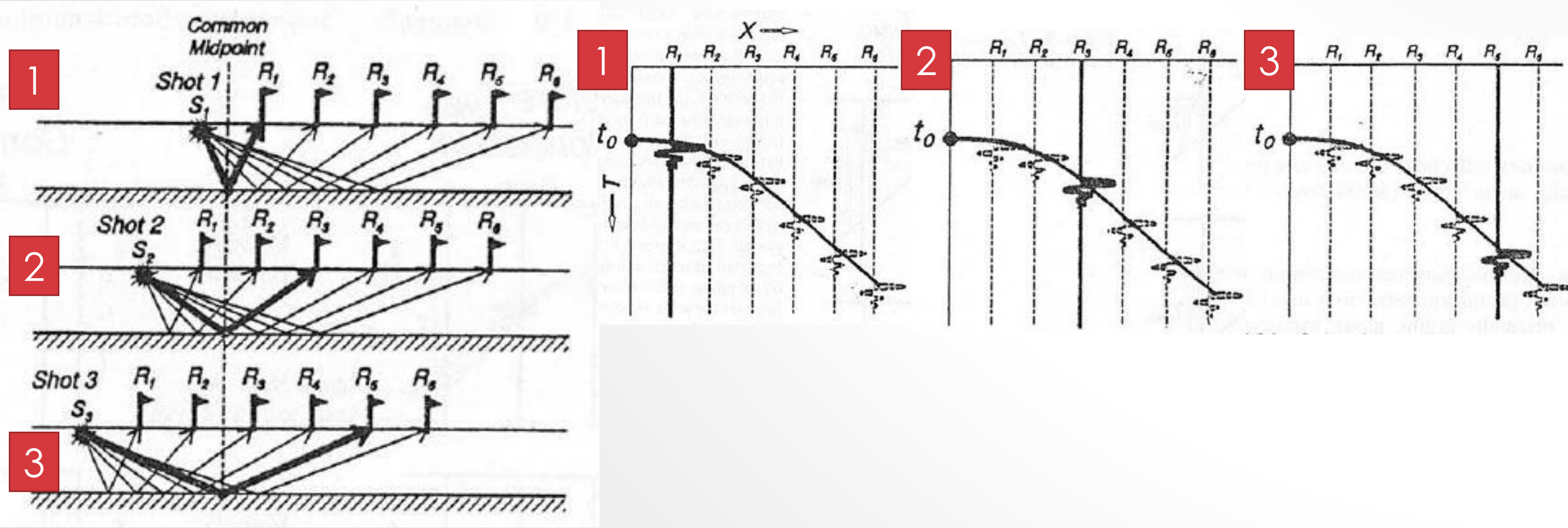
Multiple + other noise must be attenuated during processing.

PROCESSING STEPS (IN GENERAL)

1. Gather
2. Velocity analysis
3. Normal Moveout correction (T_{NMO})
4. Mute
5. Static Correction
6. Stack
7. Migration
8. Depth conversion

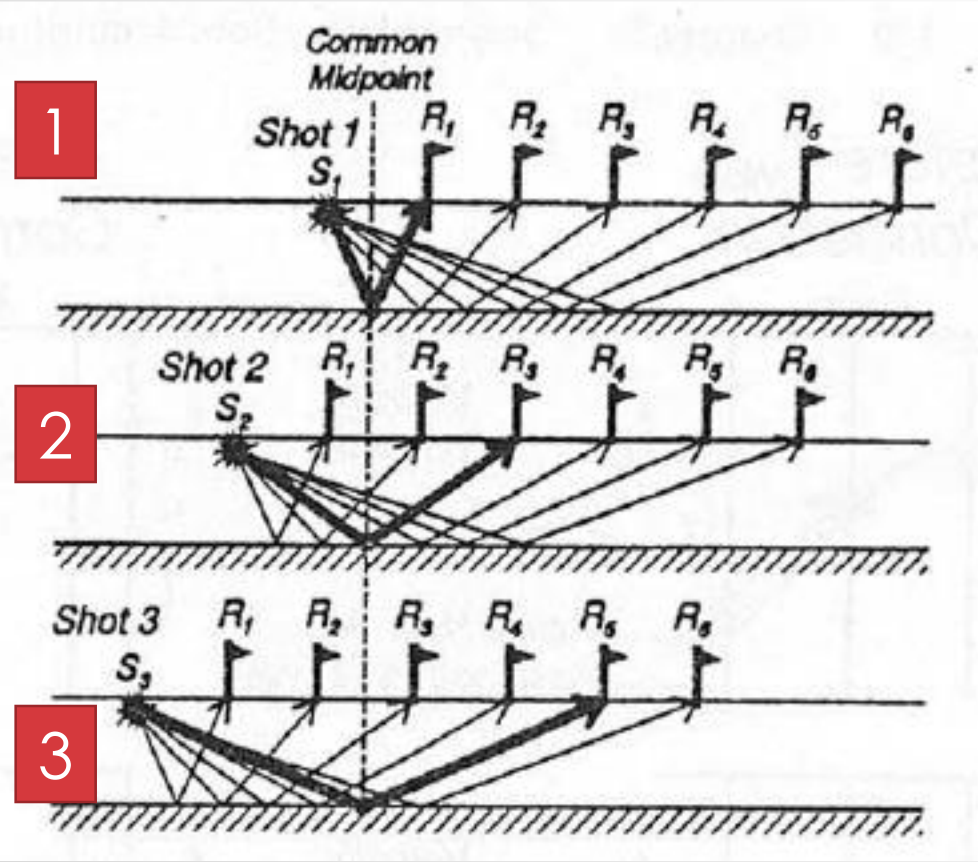
(1) GATHER

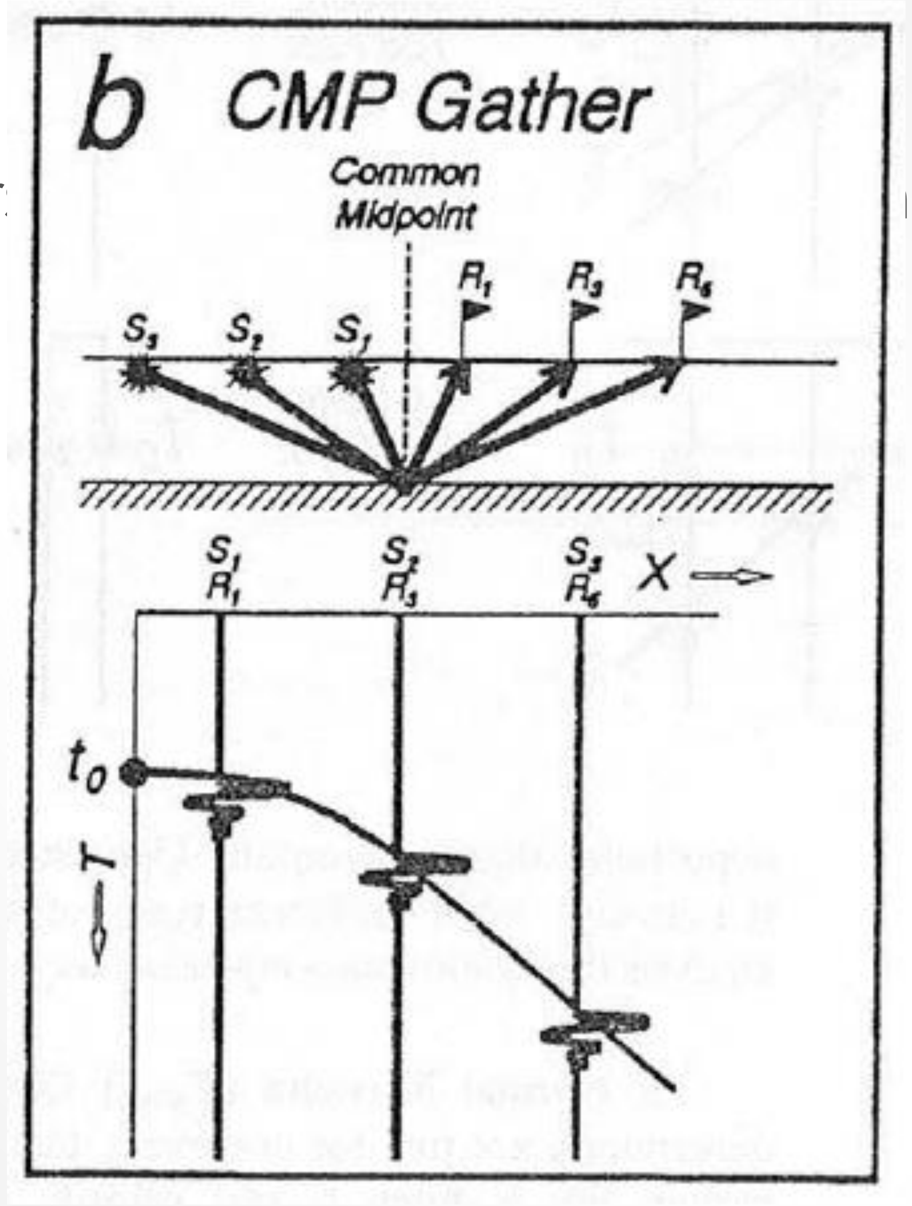
- Traces from different shot gathers are rearranged as common mid point (CMP) gathers.



(1) GATHER

- Traces from different shot gathers mid point (CMP) gathers.



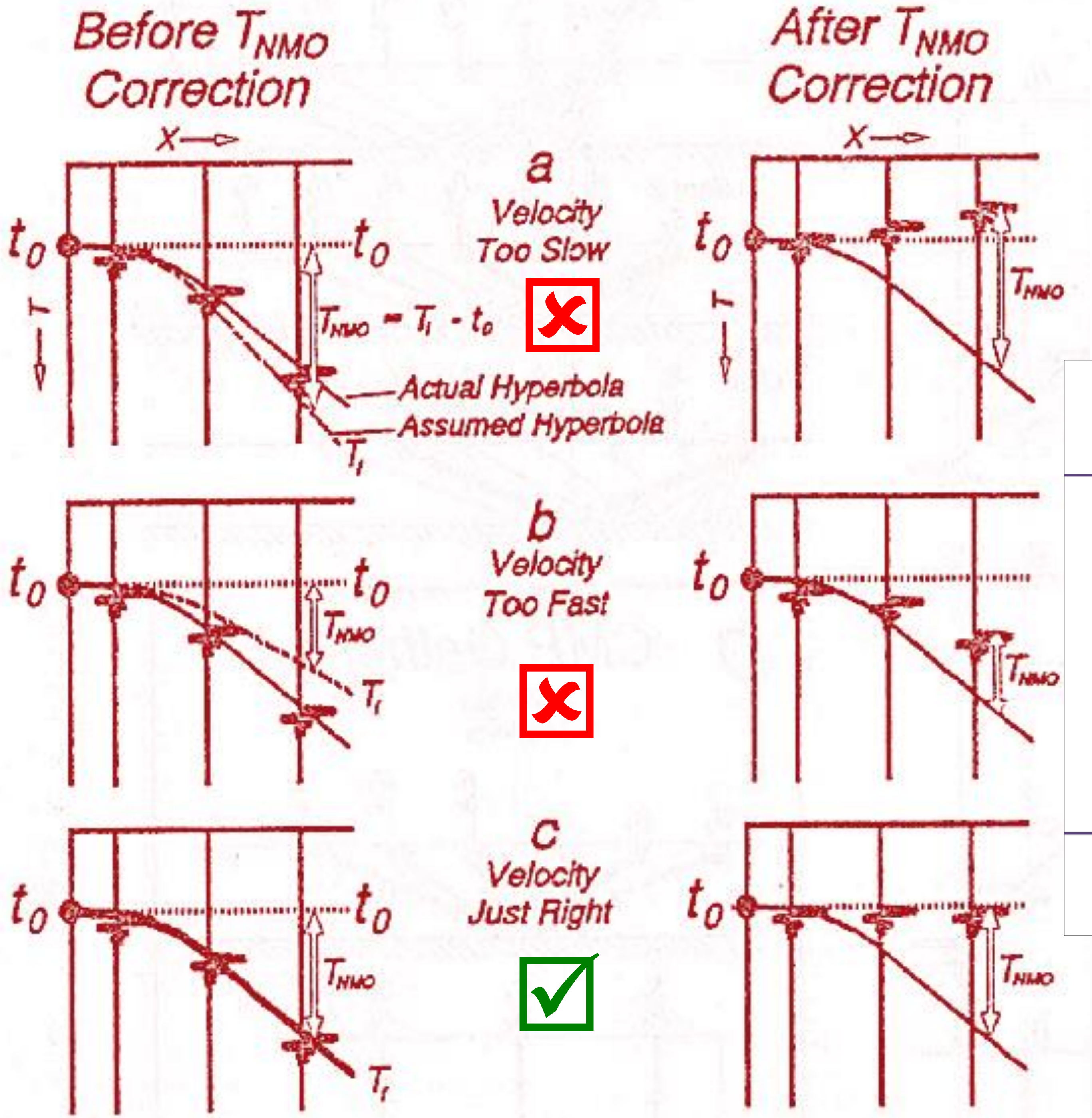


(2) VELOCITY ANALYSIS

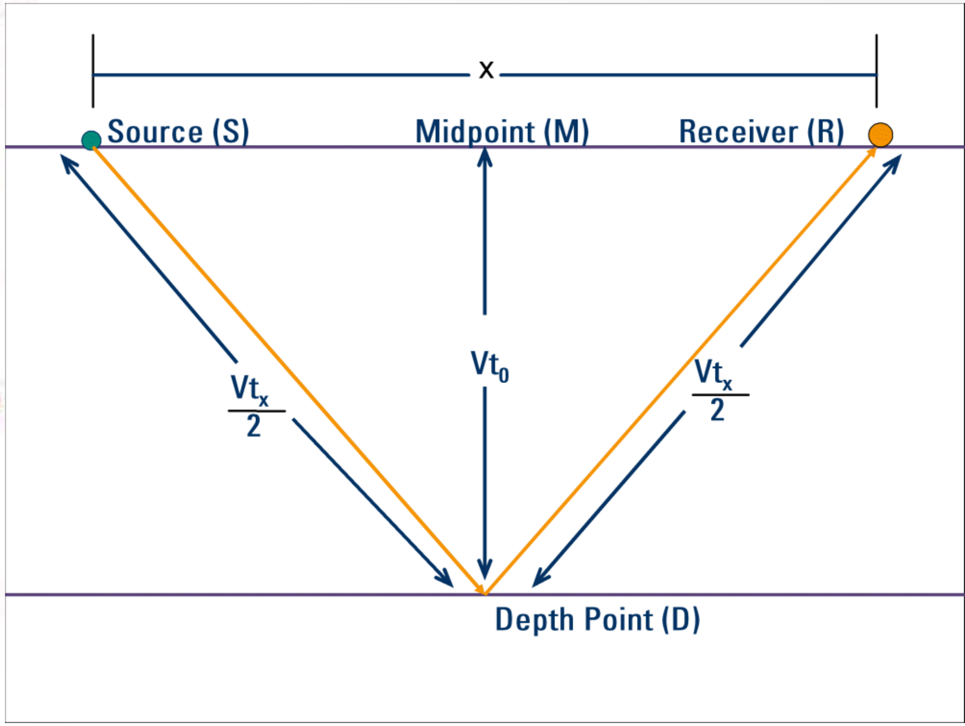
- A reflection from a horizontal interface follows a hyperbola

$$\boxed{T_r = t_0 + T_{NMO}}$$

- Velocity analysis determines velocities that best "tune" primary reflections when traces are stacked
- The process is commonly trial and error, whereby different normal moveout time (T_{NMO}) corrections are applied to traces in CMP gathers.

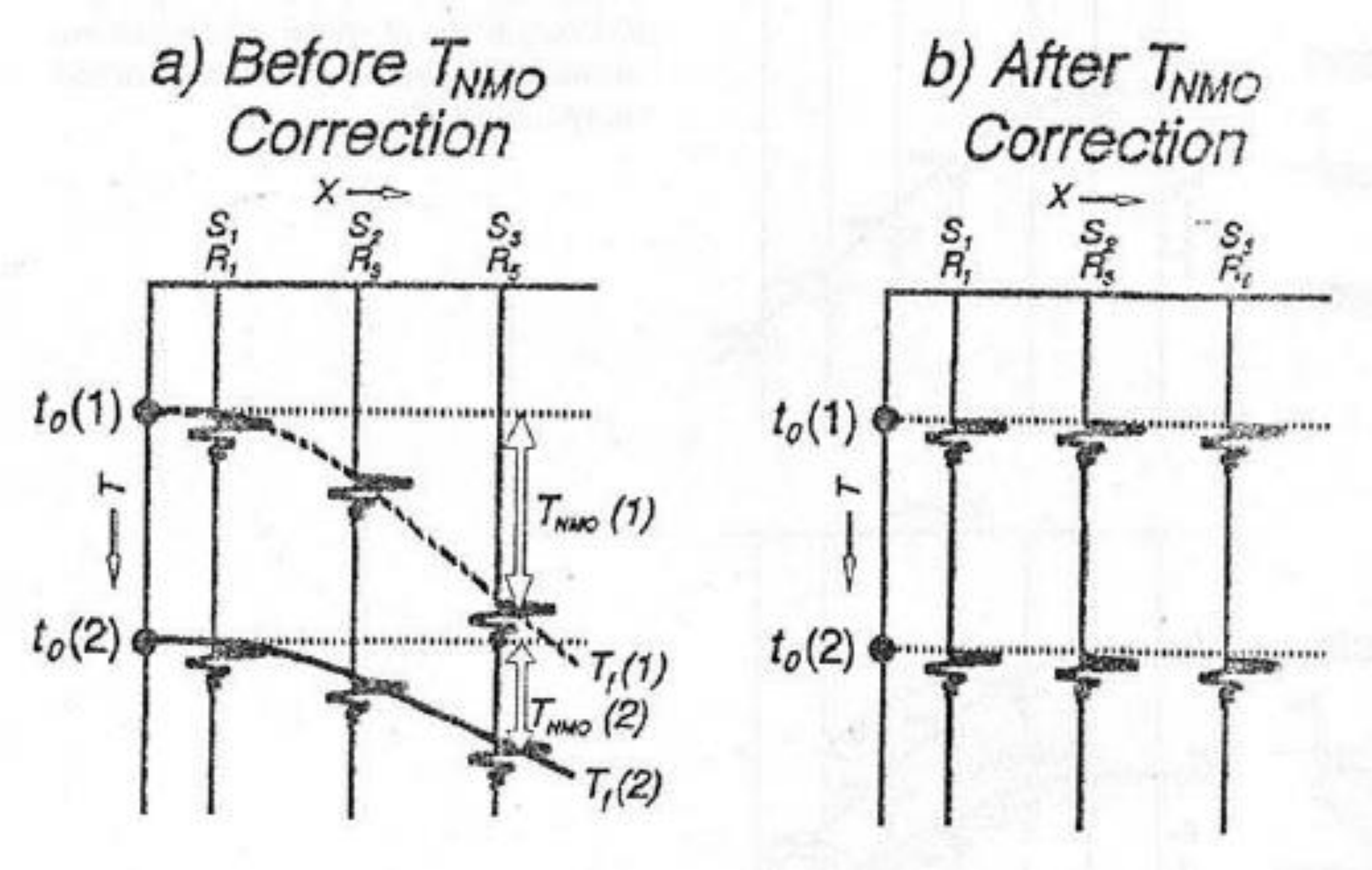


$$T_f = t_0 + T_{NMO}$$

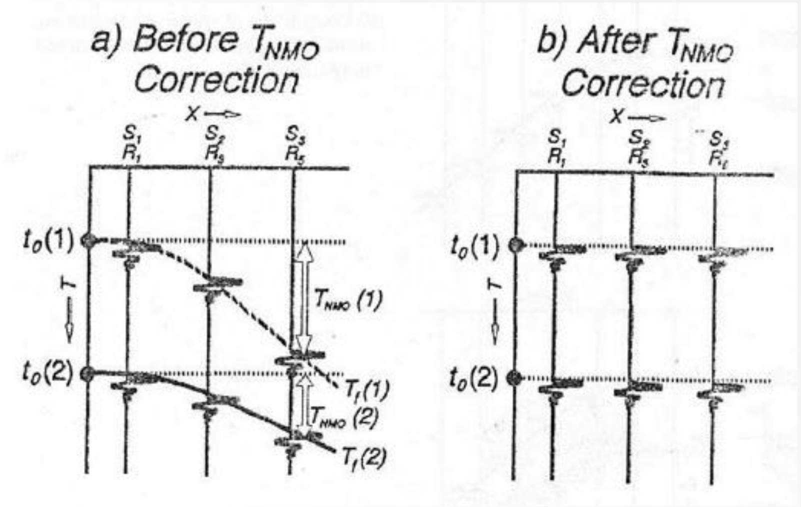


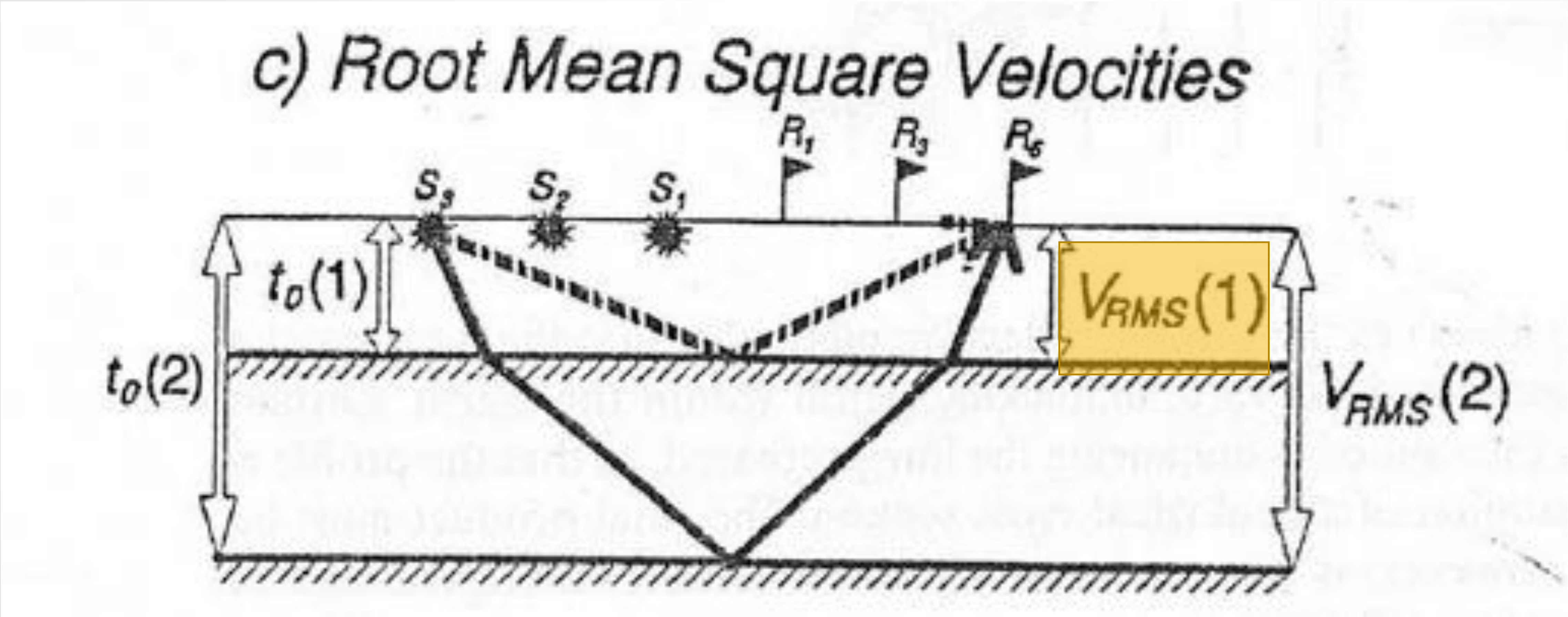
$$T_{NMO} = \frac{\sqrt{(x^2 + 4h_1^2)}}{V_1} - \frac{2h_1}{V_1}$$

(3) NORMAL MOVEOUT (T_{NMO})

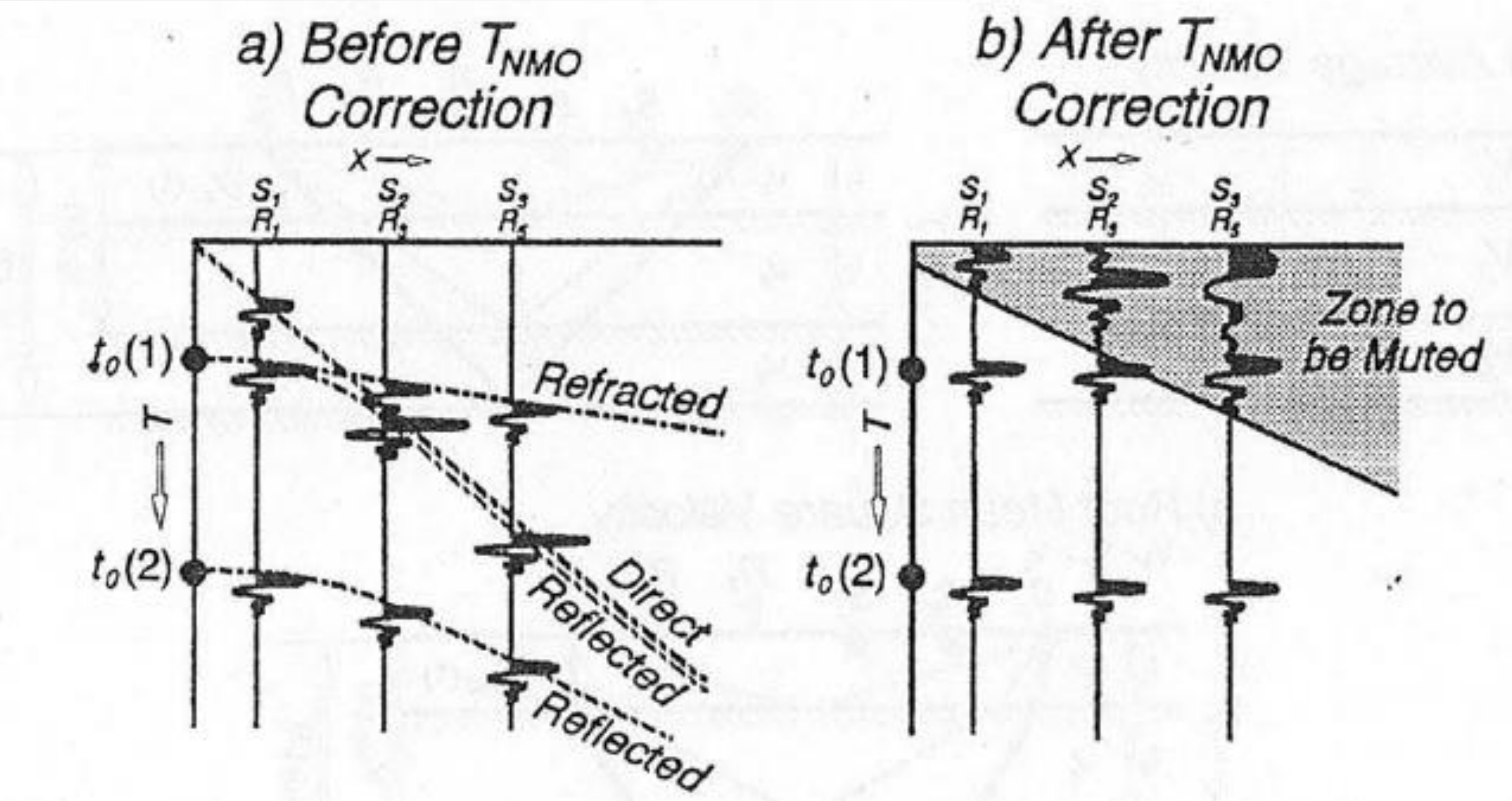


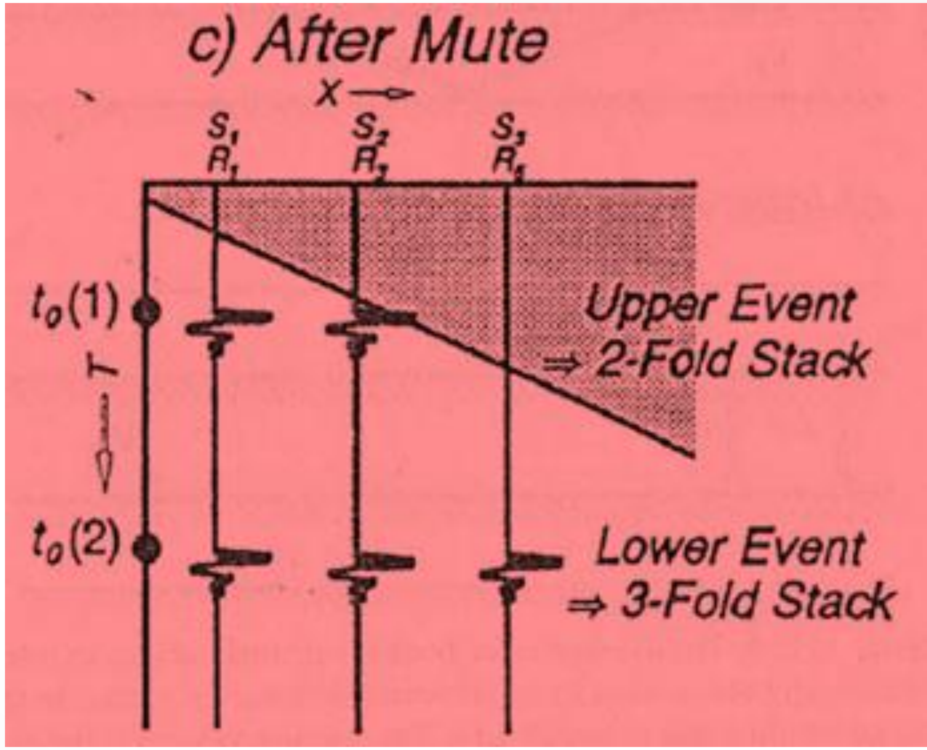
(3) NORMAL MOVEOUT (T_{NMO})





(4) MUTE

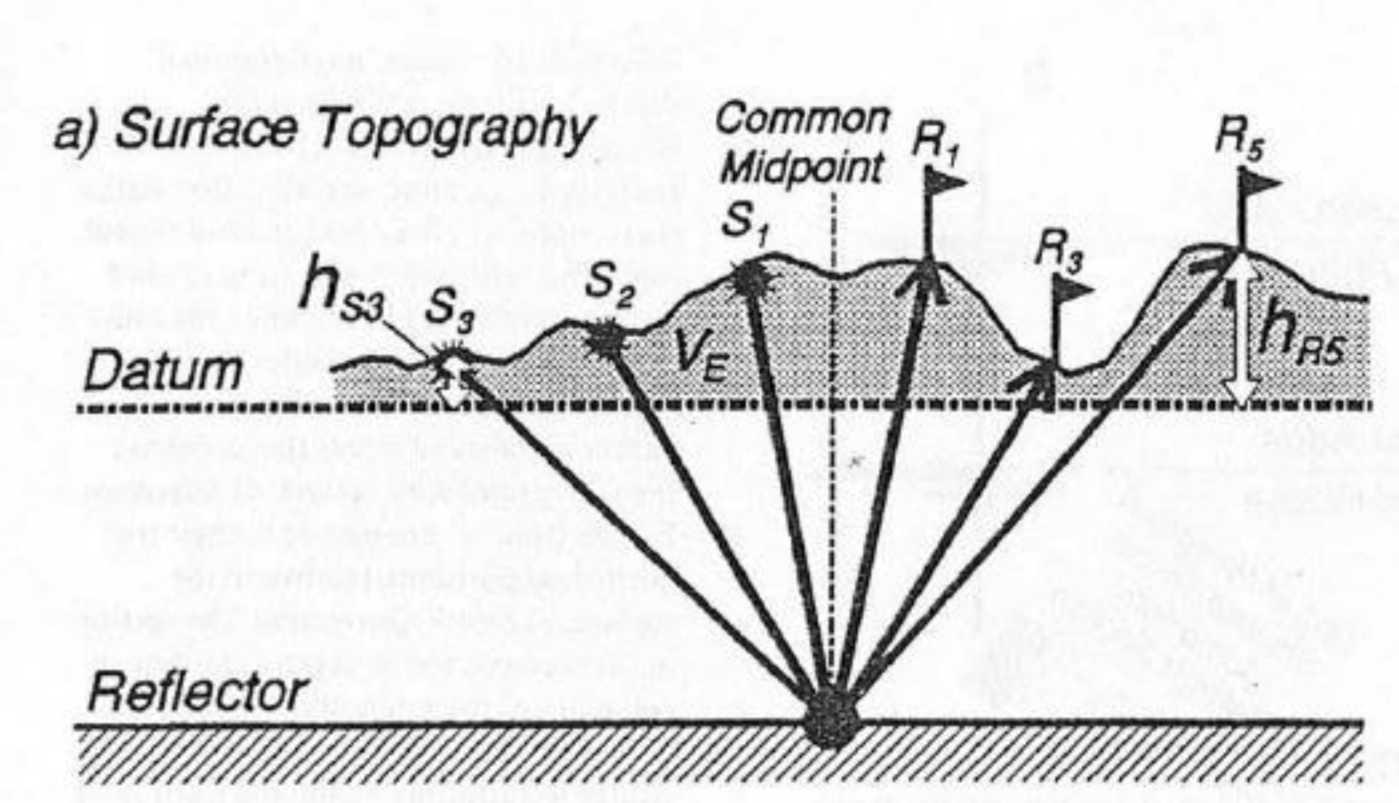

a) Before T_{NMO} Correction
x
S_1 R_1
S_2 R_2
S_3 R_3
$t_0(1)$
$t_0(2)$
T
Refracted
Direct
Reflected
Reflected
b) After T_{NMO} Correction
x
S_1 R_1
S_2 R_3
S_3 R_5
Zone to be Muted
$t_0(1)$
$t_0(2)$
T


c) After Mute
x
S_1 R_1
S_2 R_2
S_3 R_3
$t_0(1)$
$t_0(2)$
T
Upper Event
⇒ 2-Fold Stack
Lower Event
⇒ 3-Fold Stack

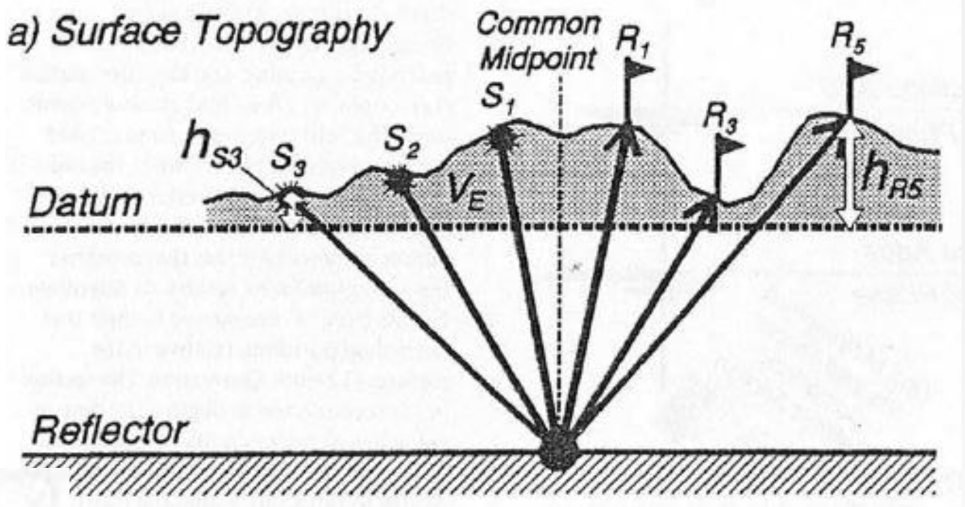
(5) STATIC CORRECTION

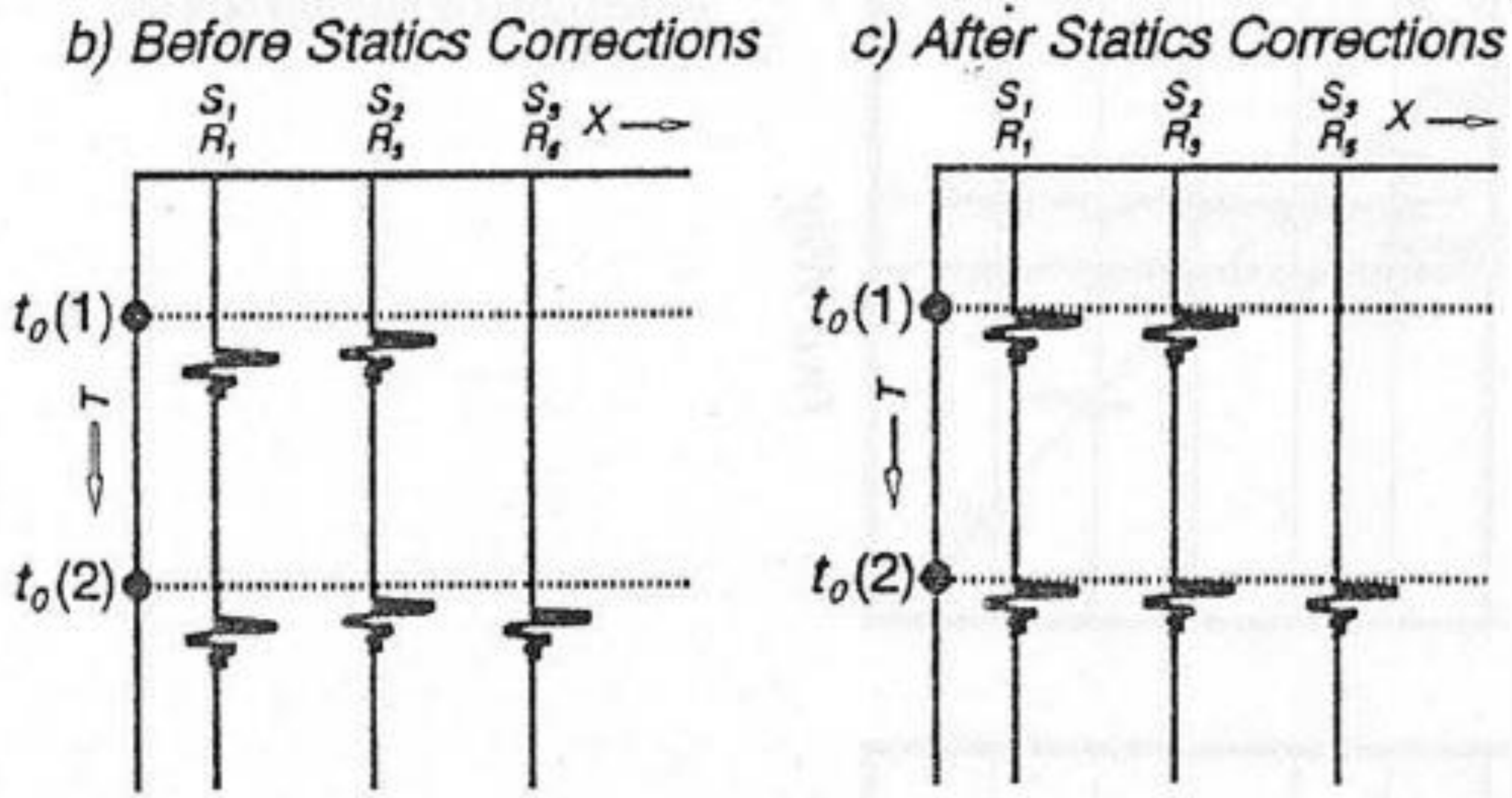
- Due to topography, the time delay correction must be applied for relatively high and lower topography, according to:

1. Estimated near surface velocity
2. The source and receiver elevation relative to a horizontal datum

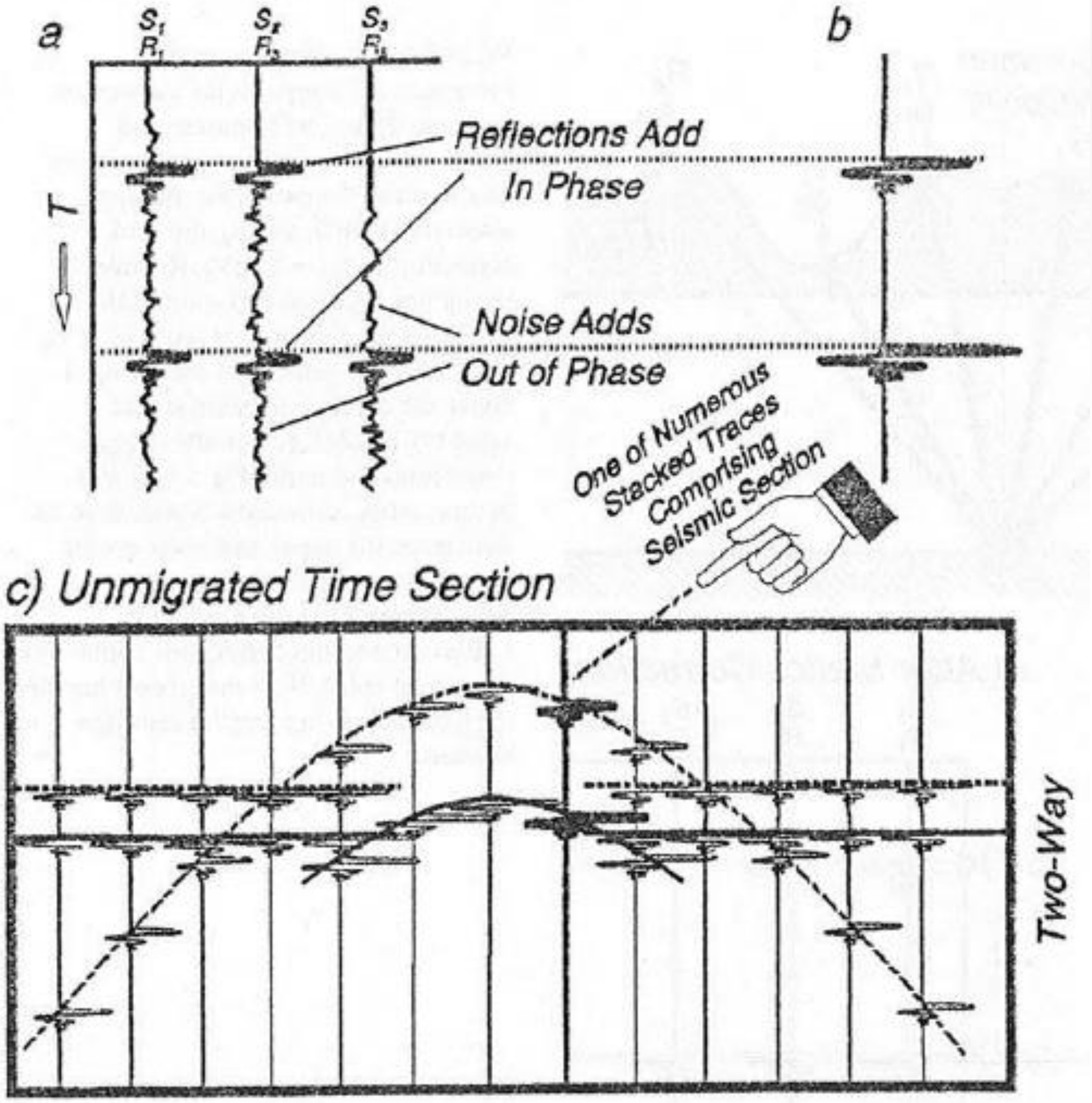


(5) STATIC CORRECTION



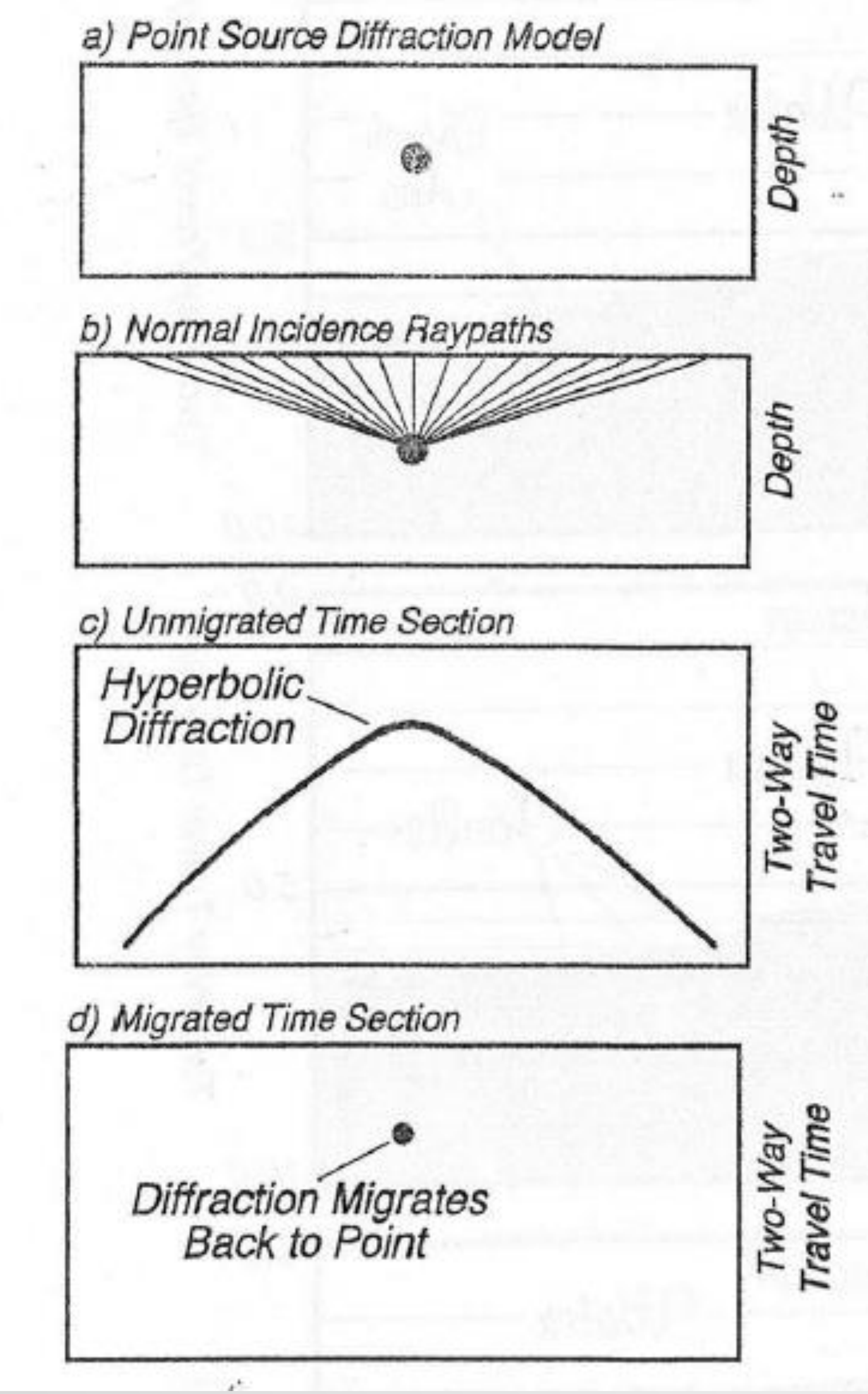


(6) STACK

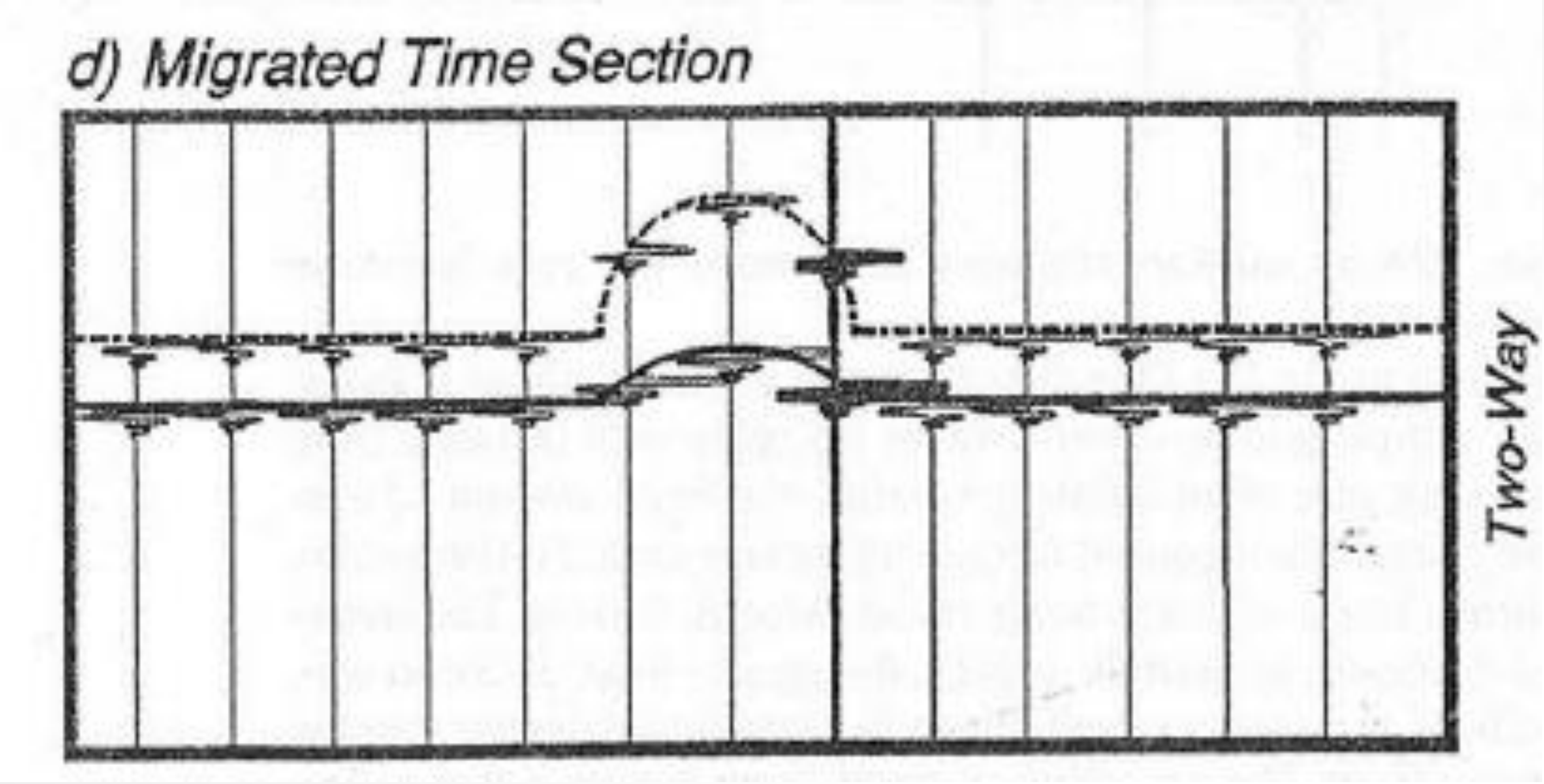


a
b
S_1 R_1
S_2 R_2
S_3 R_3
T
Reflections Add
In Phase
Noise Adds
Out of Phase
One of Numerous Stacked Traces Comprising Seismic Section
c) Unmigrated Time Section
Two-Way

(7) MIGRATION

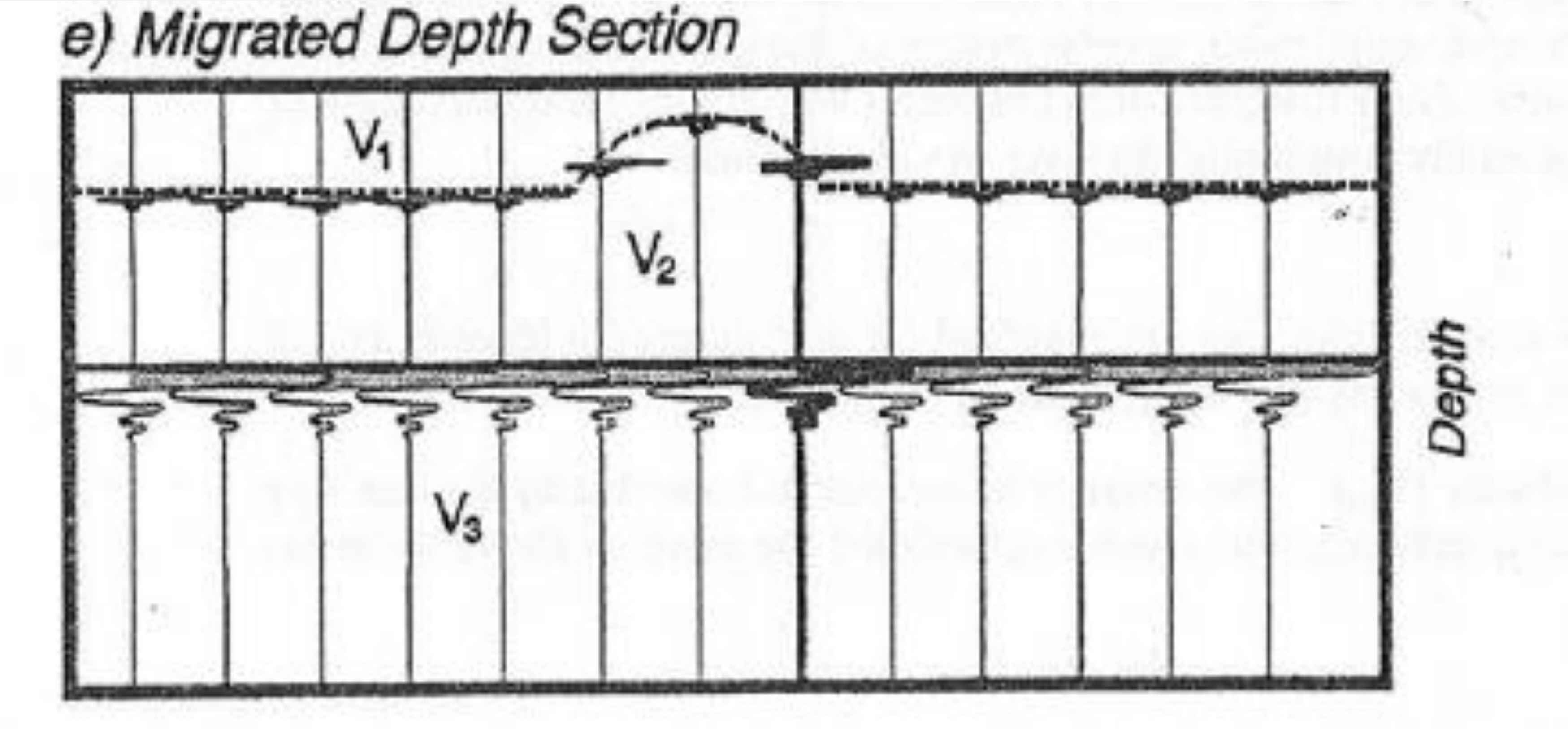


a) Point Source Diffraction Model
Depth
b) Normal Incidence Raypaths
Depth
c) Unmigrated Time Section
Hyperbolic Diffraction
Two-Way Travel Time
d) Migrated Time Section
Diffraction Migrates Back to Point
Two-Way Travel Time



d) Migrated Time Section
Two-Way

(8) DEPTH CONVERSION



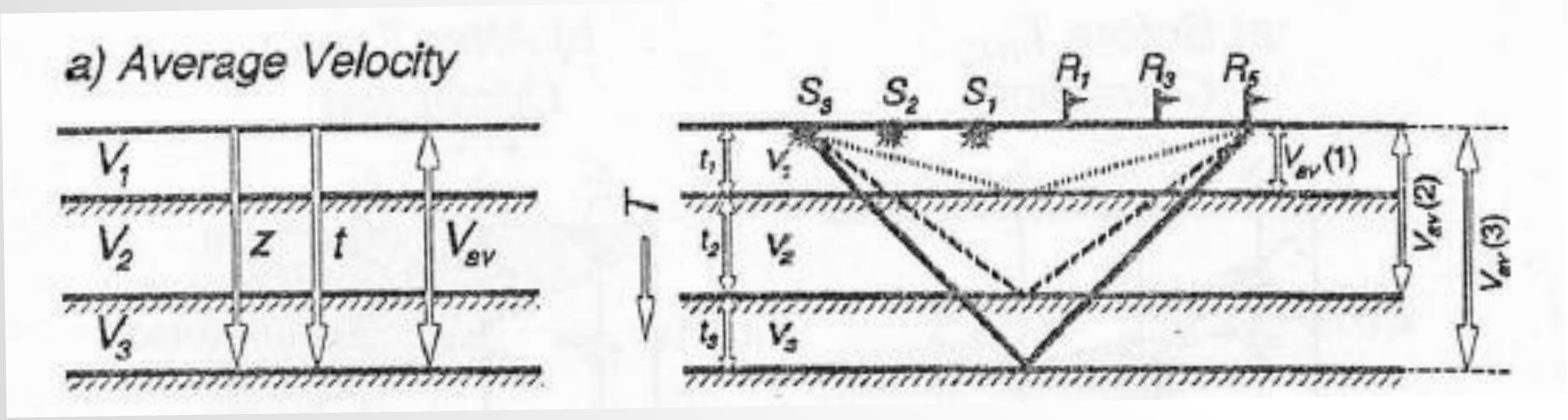
OTHER PROCESSING PROCEDURES

- Filtering 10 – 50 Hz or raw data will improve the S/N ratio
- Deconvolution to remove the reverberation effects from near surface layer
- Attenuation signal as they penetrated into the earth since (1) spherical divergences (a balloon skin concept) (2) absorption (3) reflection
- Automatic Gain Control (AGC) then performed to balances amplitudes along the length of seismic trace.

TYPES OF VELOCITY

$$V_{av} = z/t$$

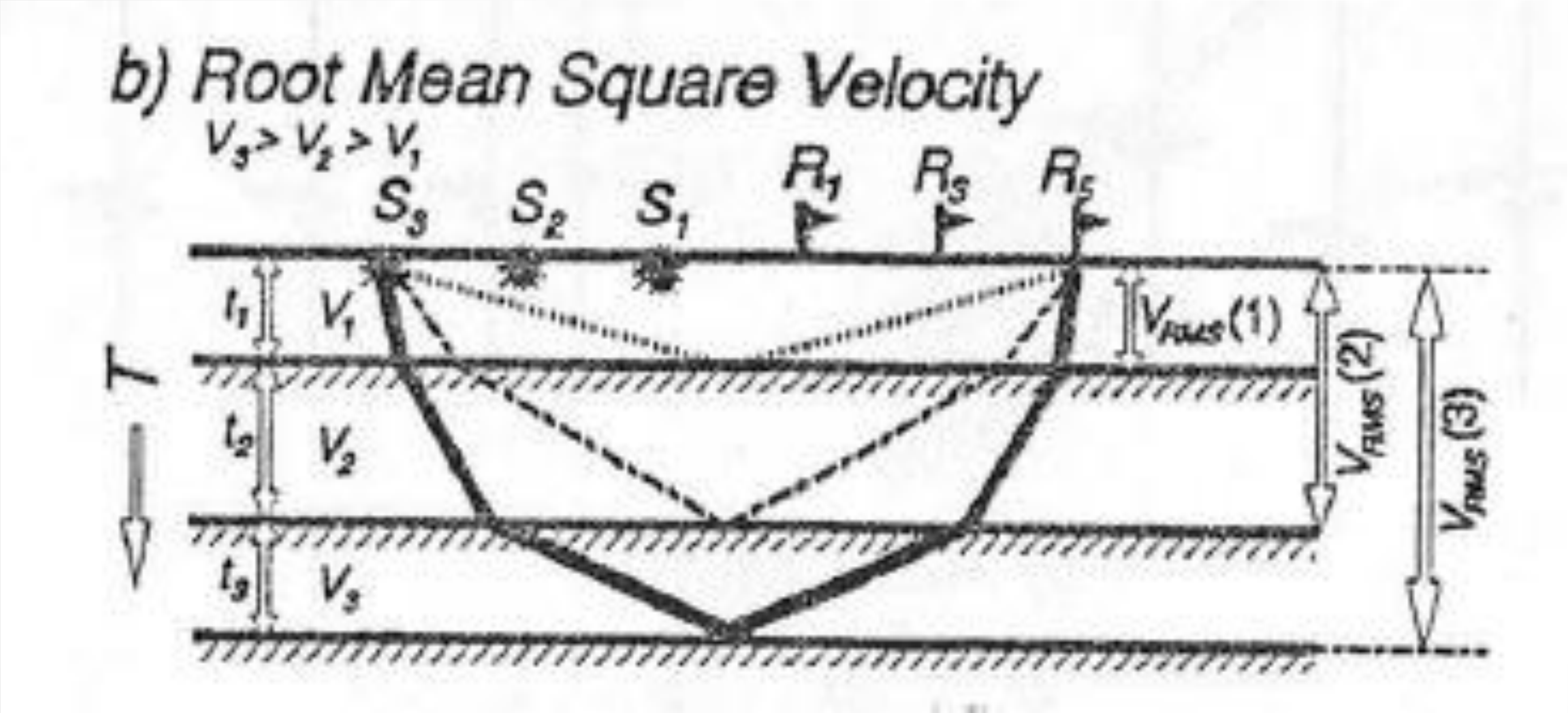
- **Average Velocity (V_{AV})**, the distance to an interface, divided by the one-way travel time to that interface, is the average velocity for the material above the interface



TYPES OF VELOCITY

$$V_{RMS} = \sqrt{\frac{\sum_{i=1}^{n} V_i^2 t_i}{\sum_{i=1}^{n} t_i}}$$

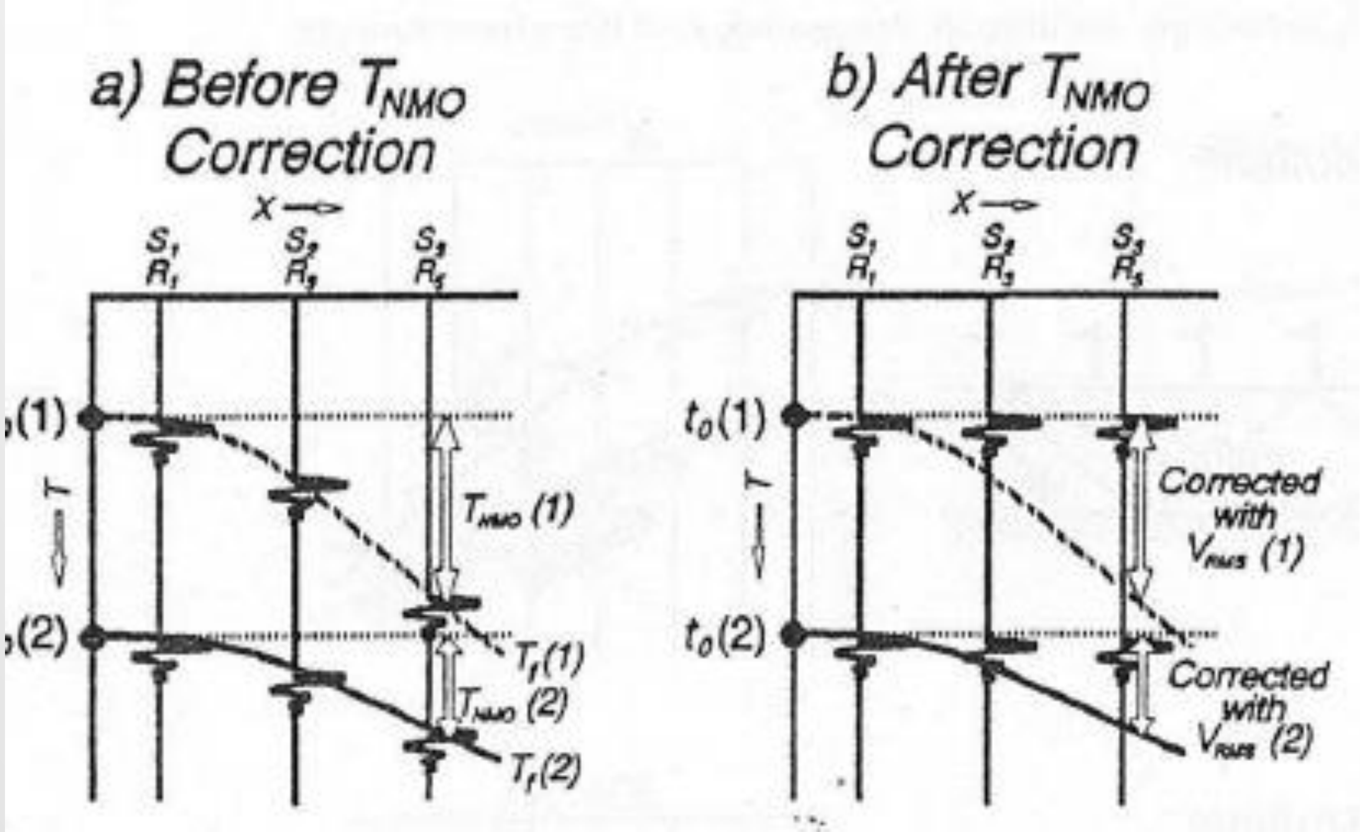
- **Root Mean Square Velocity (V_{RMS})**, is a weighted average velocity. It squaring the velocities in the $V_i t_i$ term, then taking square root to the averaged sum.



TYPES OF VELOCITY

$$V_{RMS} = \sqrt{\frac{\sum_{i=1}^{n} V_i^2 t_i}{\sum_{i=1}^{n} t_i}}$$

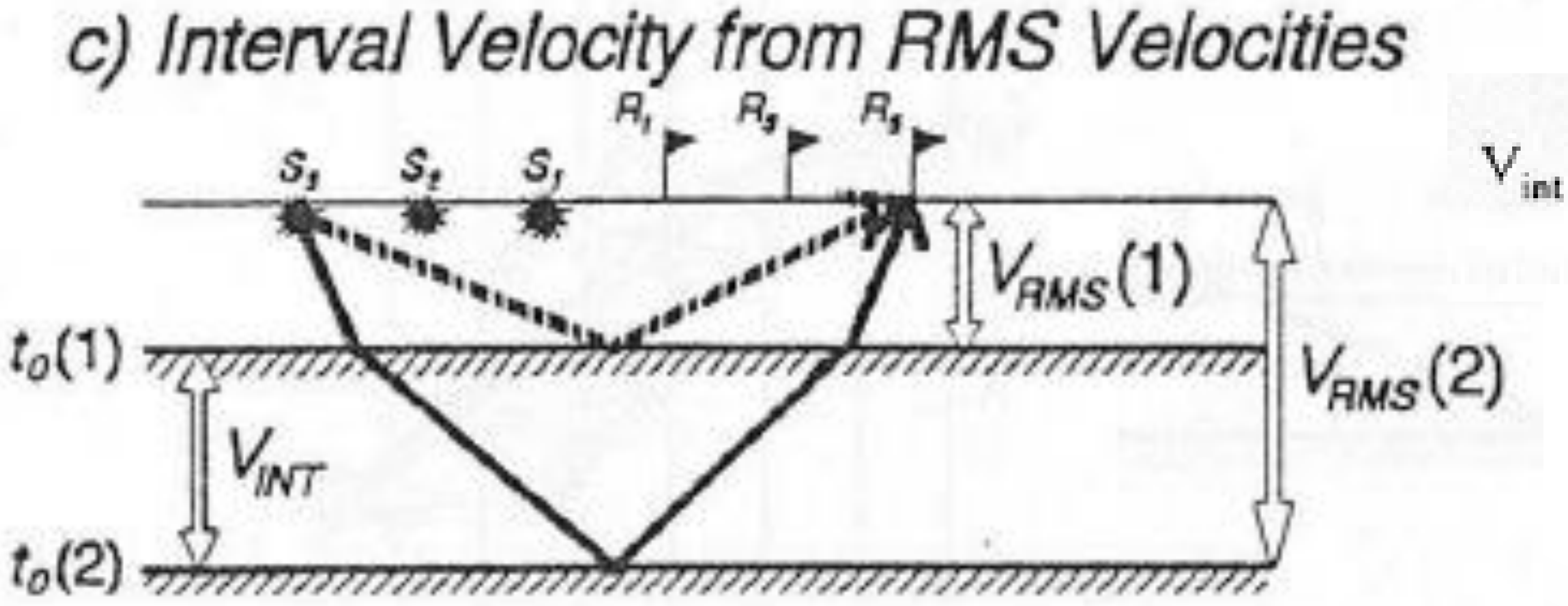
- **Stacking Velocity**, is velocity that best correct an event on a CMP gather for normal moveout. It is an approximation of the RMS velocity for material above the reflecting interface.



$$V_{int} = \Delta z / \Delta t$$

TYPES OF VELOCITY

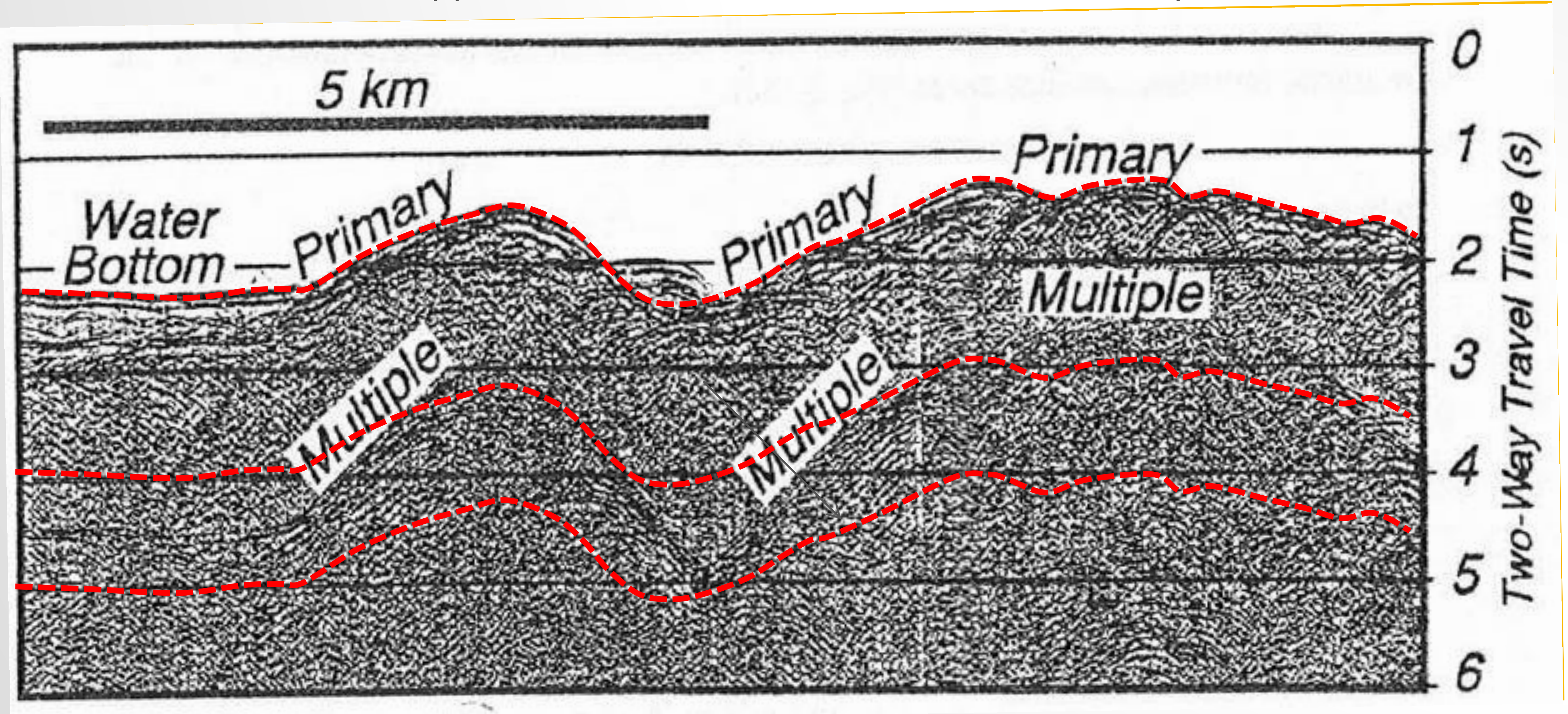
- **Interval Velocity**, is the average velocity of the material between two interfaces.



$$V_{int} = \sqrt{\frac{V_2^2 t_2 - V_1^2 t_1}{t_2 - t_1}}$$

MULTIPLES

- Are common type of noise on seismic reflection profiles.



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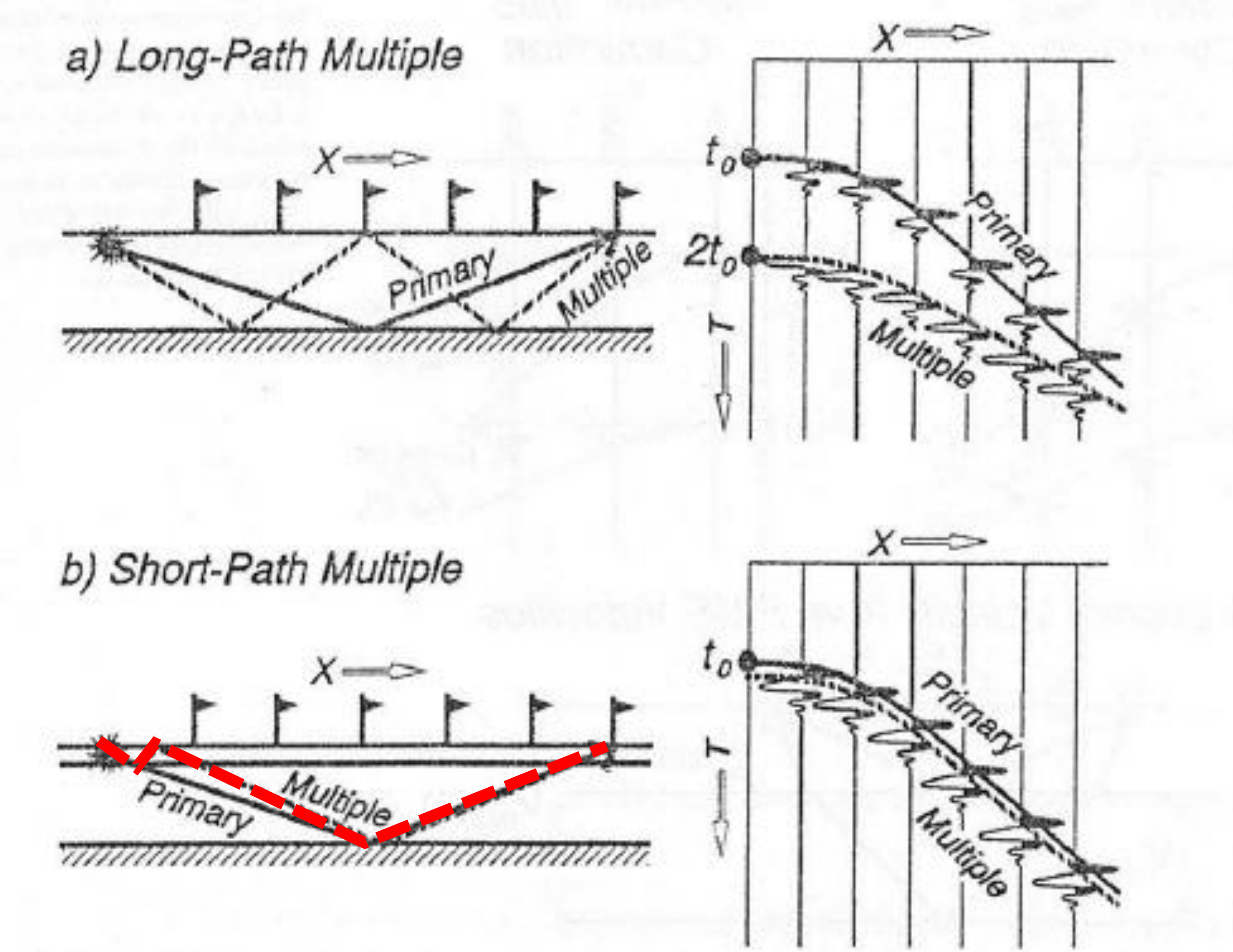
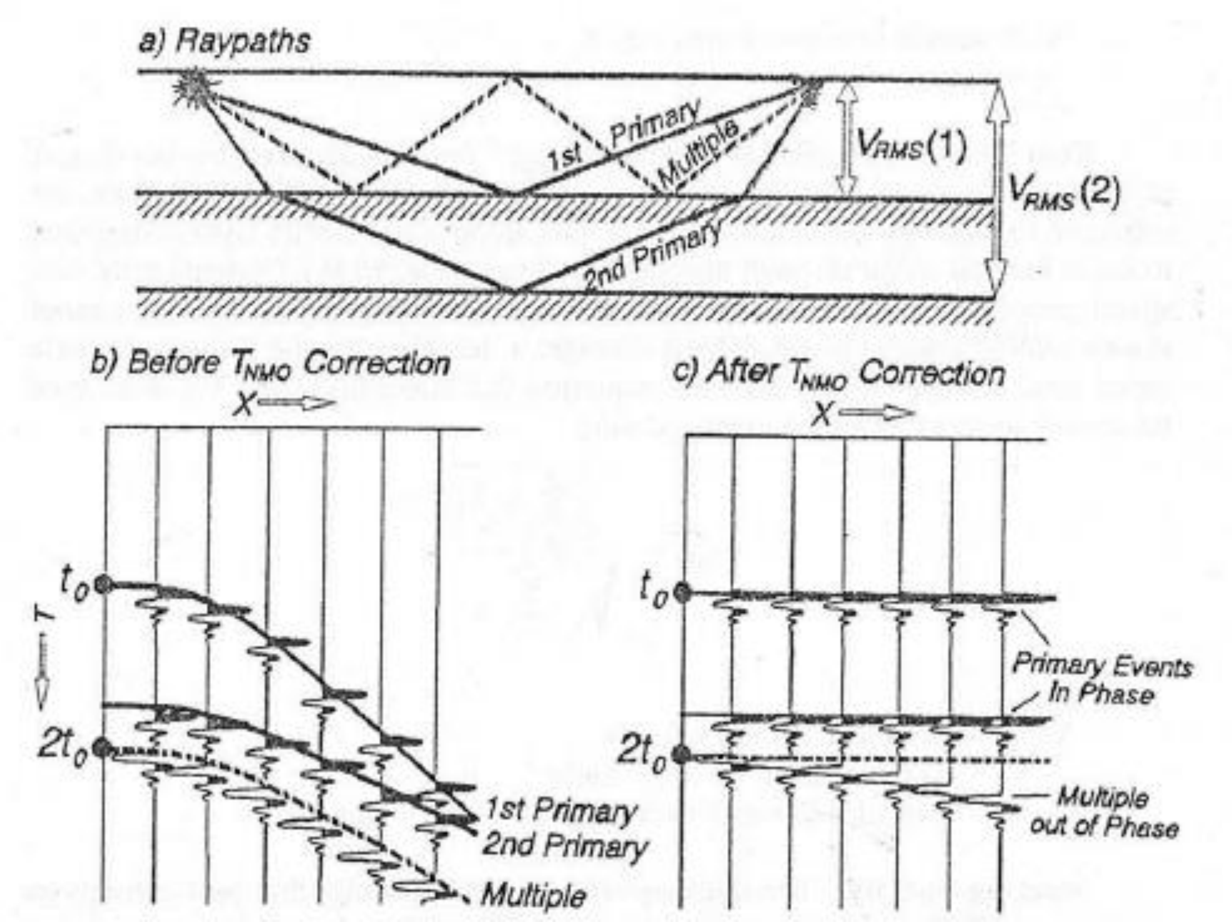


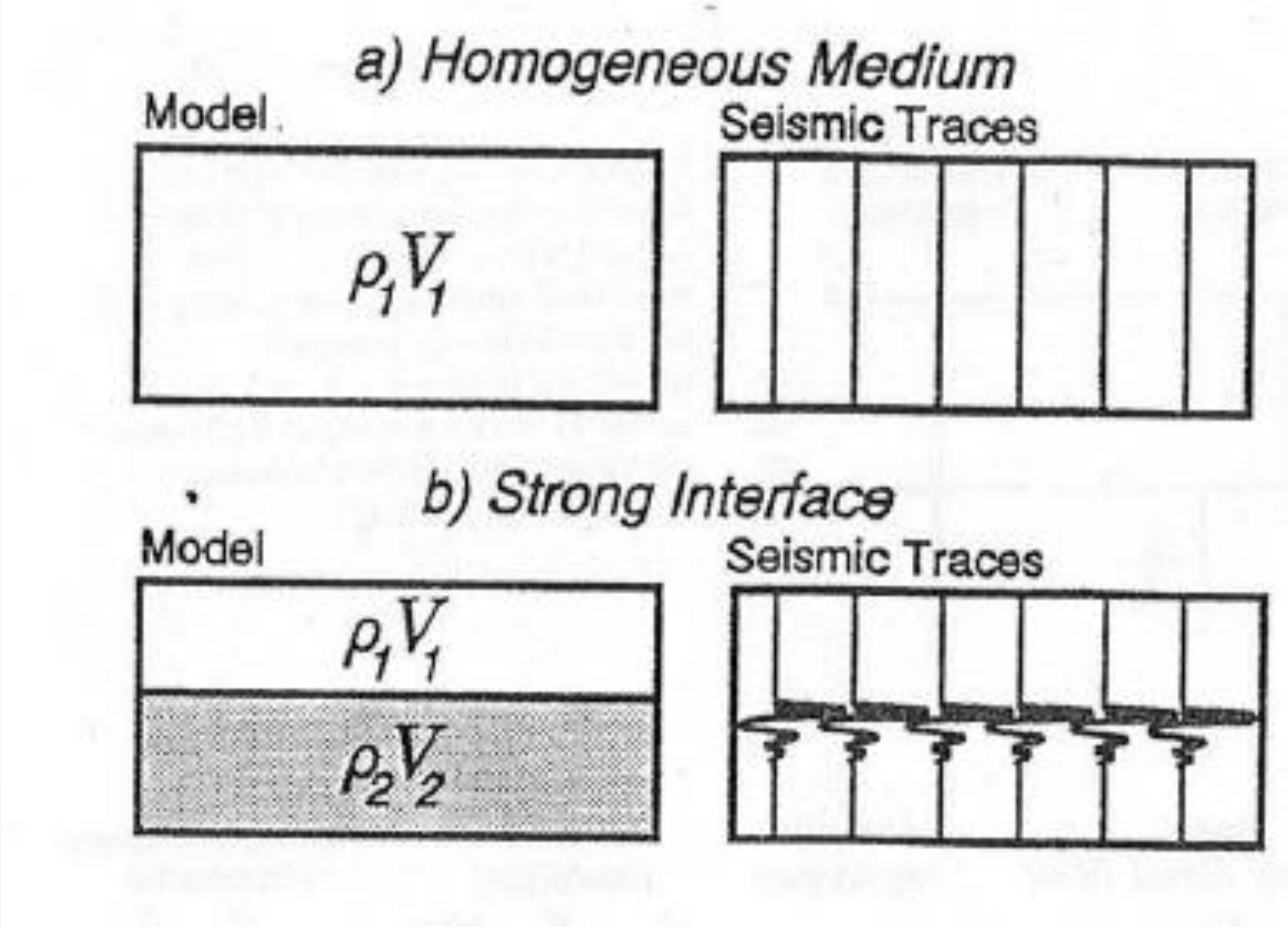
Peg-leg multiple

MULTIPLES

- Normal processing of normal moveout correction and stacking will attenuate multiples

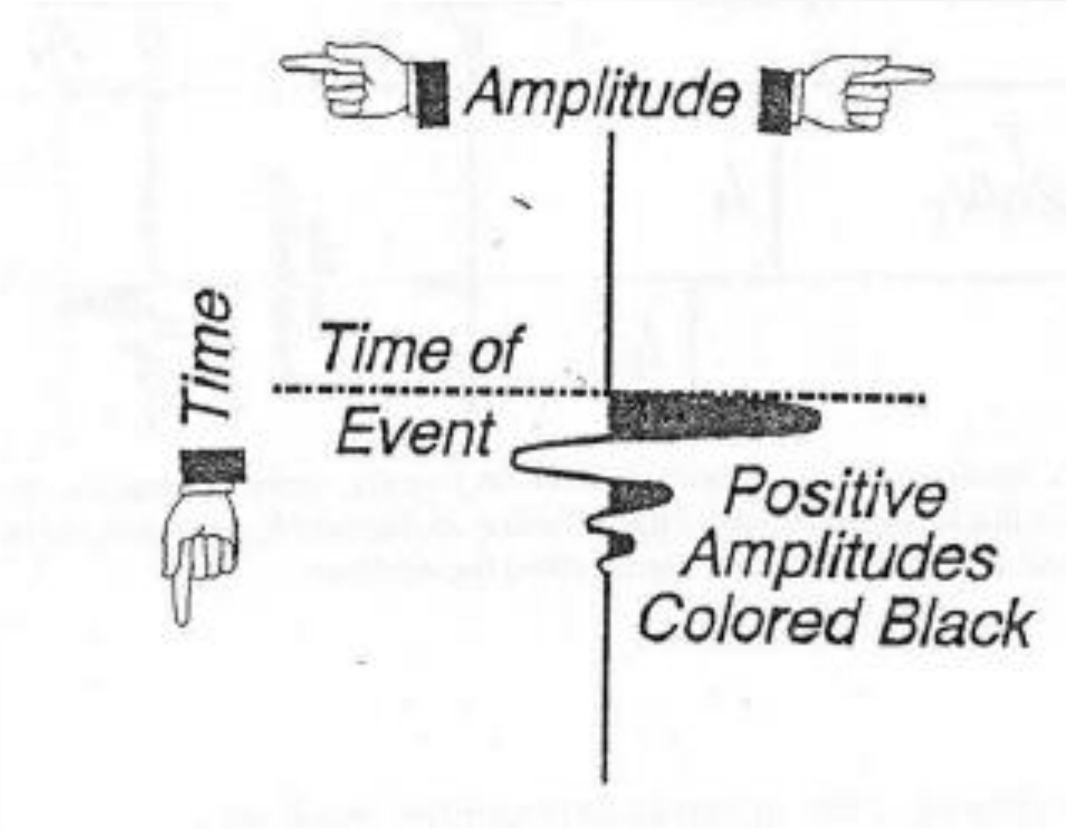


SEISMIC WAVEFORM



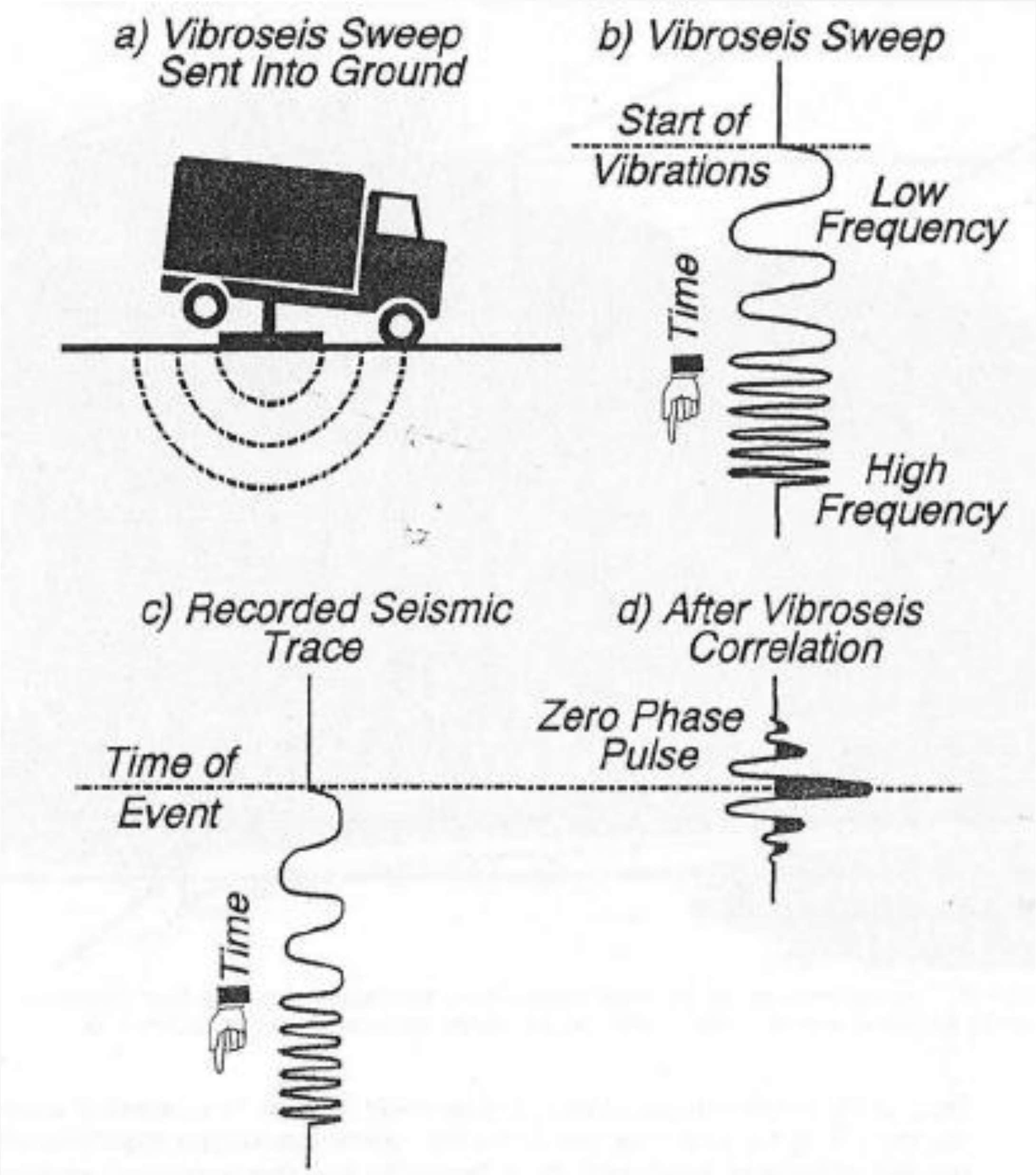
SEISMIC WAVEFORM

- A **Minimum Phase Pulse** – an explosive source, as dinamite or land or air gun at sea results in a burst of energy near the time of the event, followed by reverberation that diminished by time.



SEISMIC WAVEFORM

- A **Zero Phase Pulse** – a symmetrical waveform about the time of event. This can be obtained using a vibroseis seismic source



WIDTH OF SEISMIC PULSE

$$V = f\lambda$$

V = seismic velocity
f = frequency
λ = wavelength.

- A typical reflection survey contains frequencies in range of 10 – 50 Hz (1 Hz = 1 cicle/s). For frequency of 30 Hz, seismic velocity 300 m/s the wavelength is

$$\lambda = \frac{3000 \text{ m/s}}{30 \text{ \~{}/s}} = 100 \text{ m}$$

WIDTH OF SEISMIC PULSE

$V = f\lambda$

V = seismic velocity
f = frequency
λ = wavelength.

Picture taken from:
Wikipedia

ACOUSTIC IMPEDANCE

- The amount of energy reflected back from an interface between two layer depend on the differences in the

$$I = \rho V$$

where:

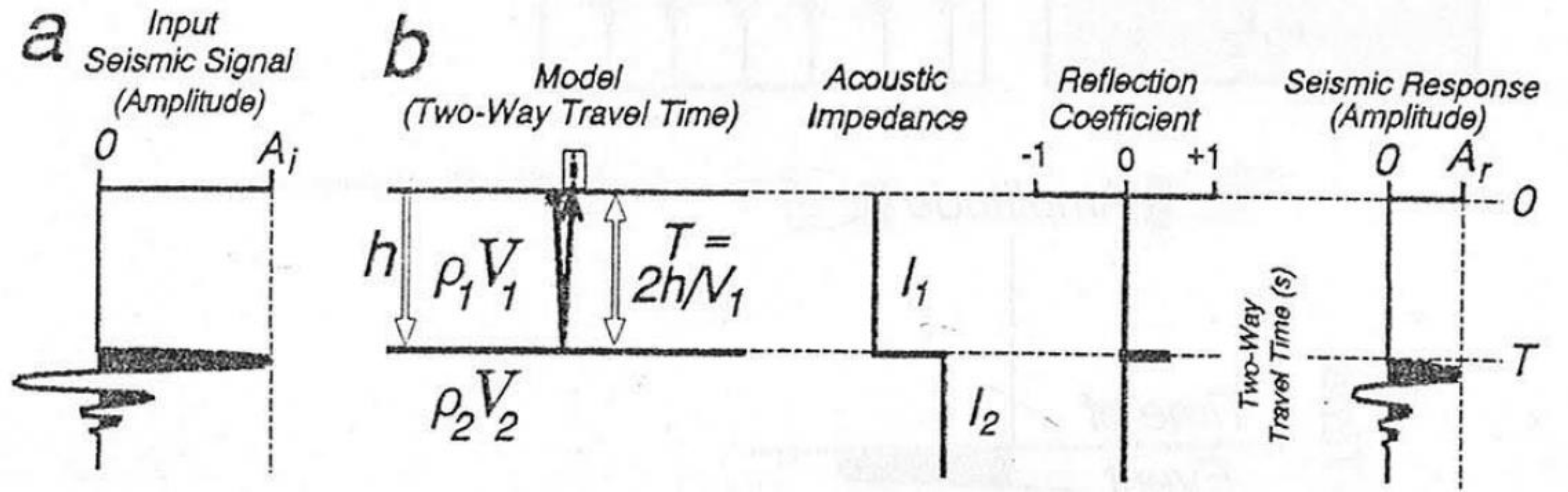
I = acoustic impedance
ρ = density
V = seismic velocity.

- The reflection coefficient express the amplitude and polarity of the wave reflected from an interface, relative to the incident wave. It depends on the **Acoustic Impedance (AI)**

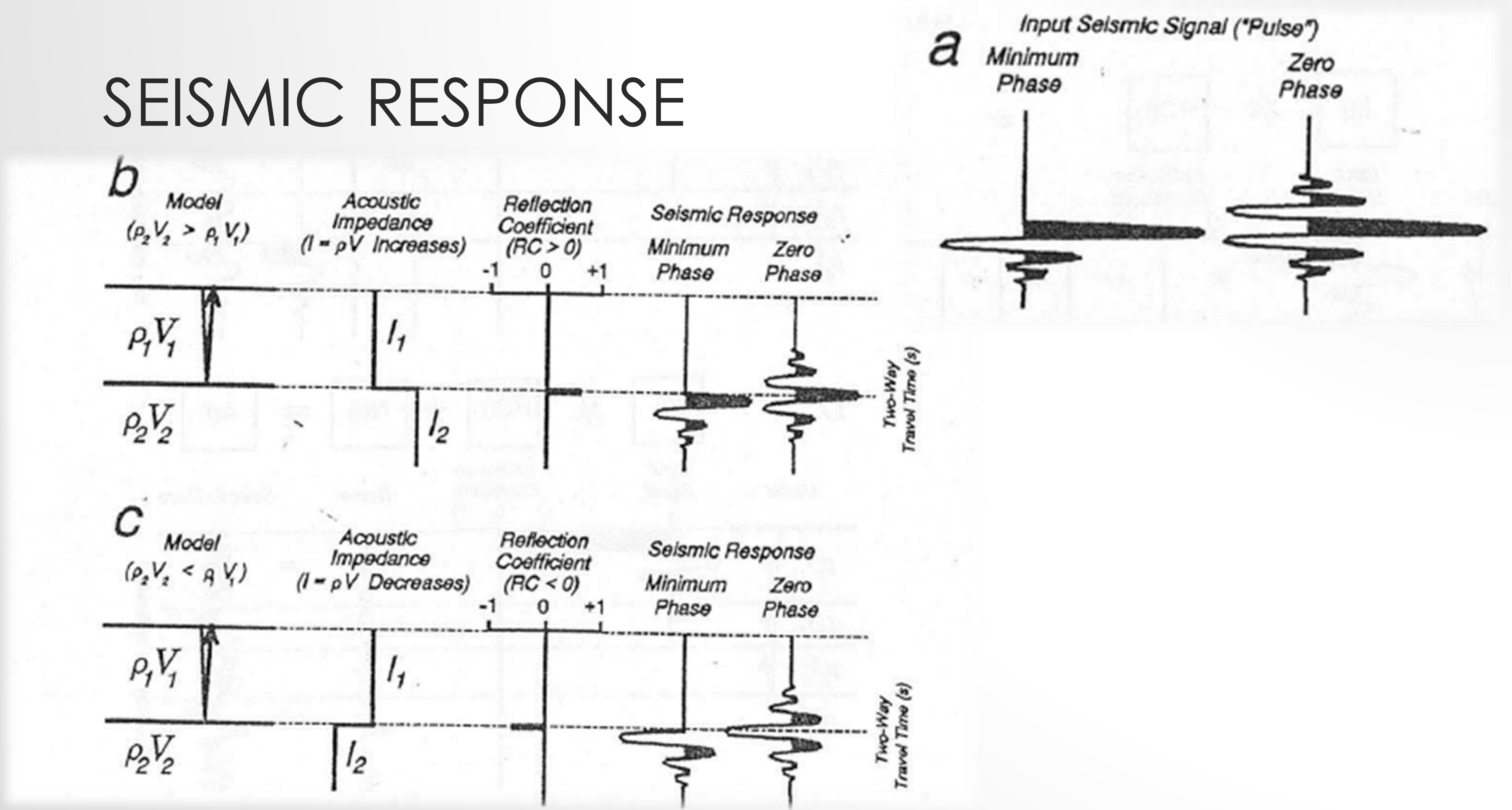
$$RC = \frac{(I_2 - I_1)}{(I_2 + I_1)} = \frac{(\rho_2 V_2 - \rho_1 V_1)}{(\rho_2 V_2 + \rho_1 V_1)}$$

ACOUSTIC IMPEDANCE

$$RC = \frac{(I_2 - I_1)}{(I_2 + I_1)} = \frac{(\rho_2 V_2 - \rho_1 V_1)}{(\rho_2 V_2 + \rho_1 V_1)}$$

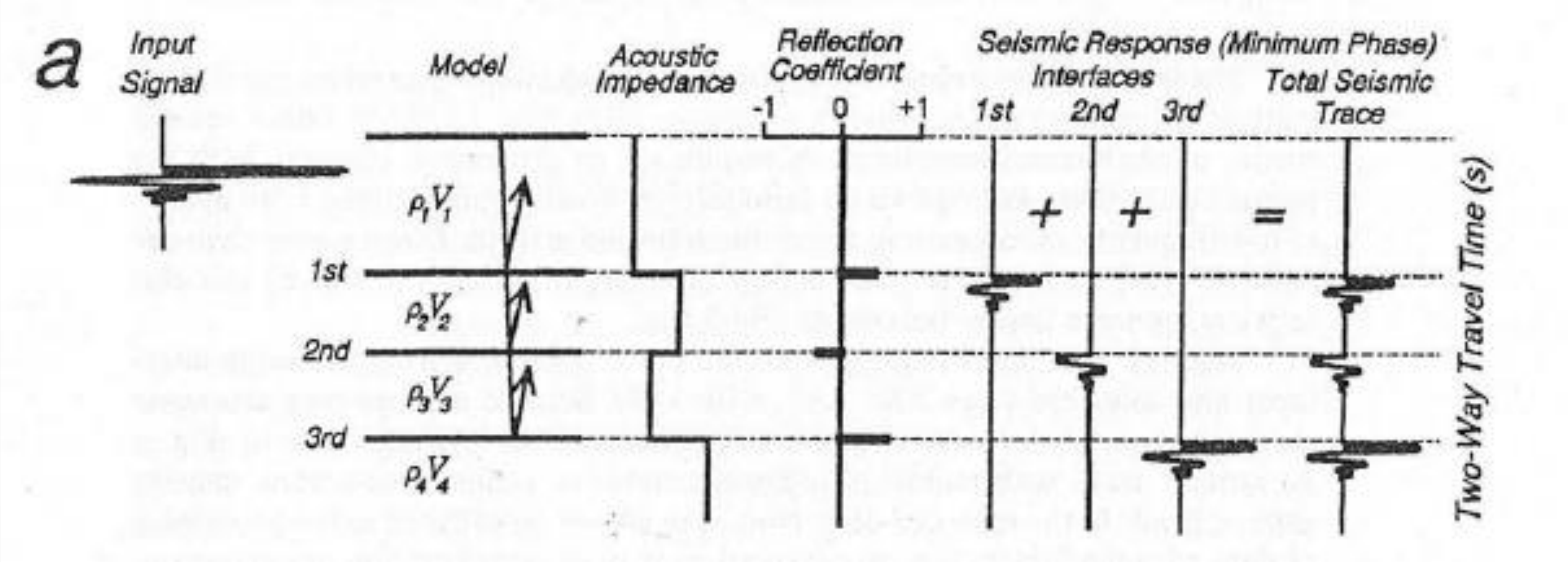


SEISMIC RESPONSE



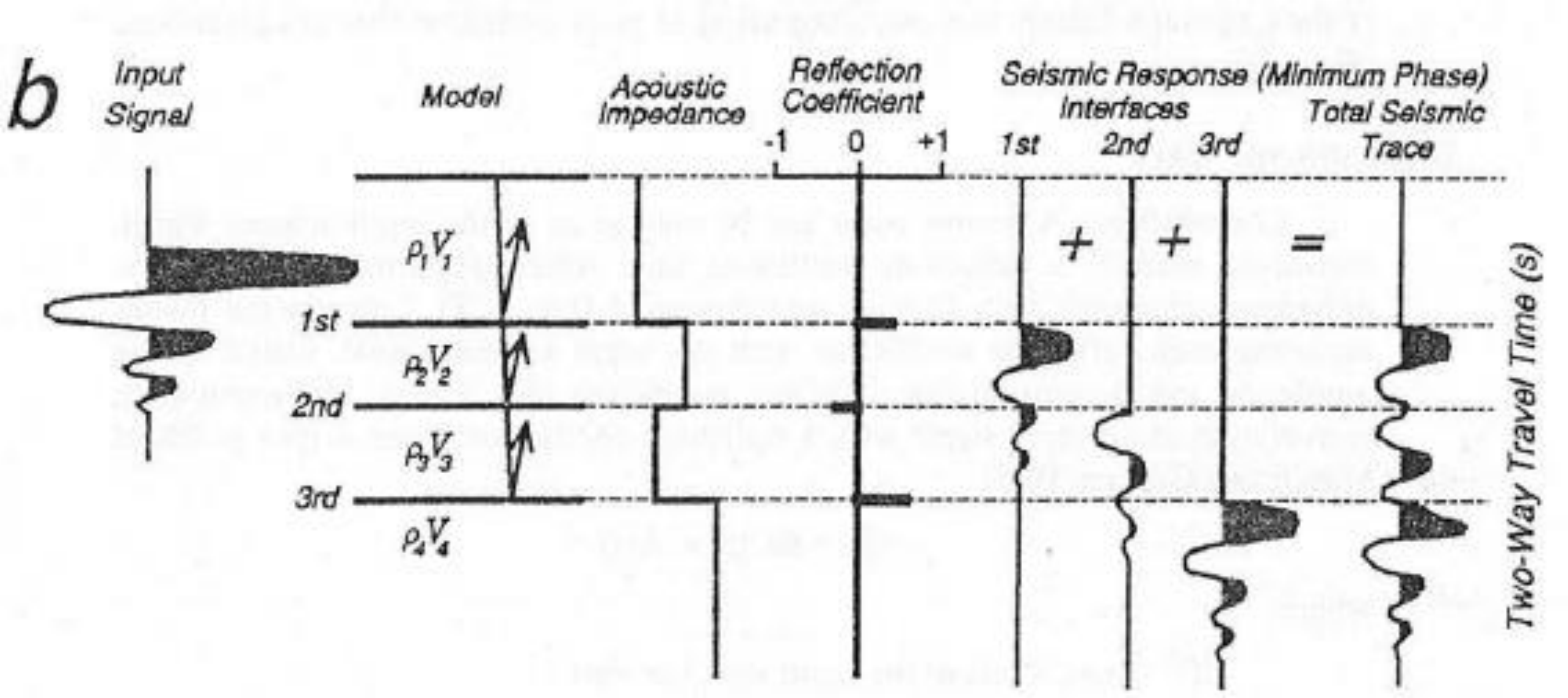
REFLECTION FROM SEVERAL INTERFACES

High frequency input signal



REFLECTION FROM SEVERAL INTERFACES

Low frequency input signal



NOISE

- The deflection of a seismic trace caused by anything other than energy reflected once from an interface
- **Natural noise**: seismic receiver (geophones) can be shaken as the result of natural phenomena. The wind shakes tree bushes and other object, animal walking near geophone, water flowing nearby stream, or wind, animal and rain shaking the cables of geophone
- **Cultural noise**: people activities; cars, trucks, trains, people walking electrical power lines

SEISMIC TRACE

- A seismic trace can be viewed as (1) the input seismic signal, convolved by (2) a reflection coefficient time series as results of acoustic impedance changes + (3) noise
- Convolution means: replacing each reflection coefficient with the input signal, scaled to the amplitude and polarity of the reflection coefficient

$$I(t) * RC(t) = A(t)$$

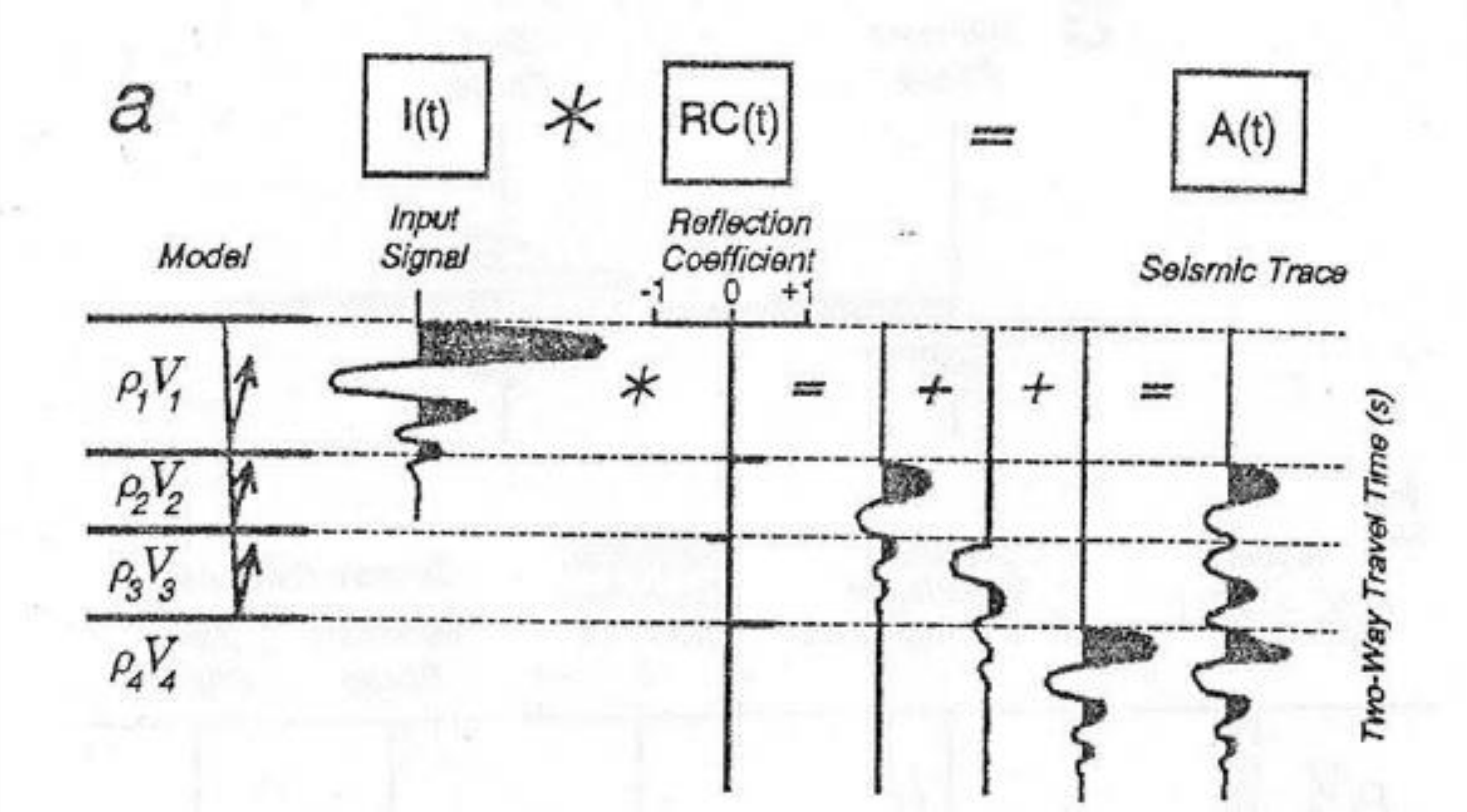
where:

$I(t)$ = amplitude of the input signal at time t
$*$ = convolution operator
$RC(t)$ = amplitude of the reflection coefficient at time t
$A(t)$ = amplitude of the seismic trace at time t.

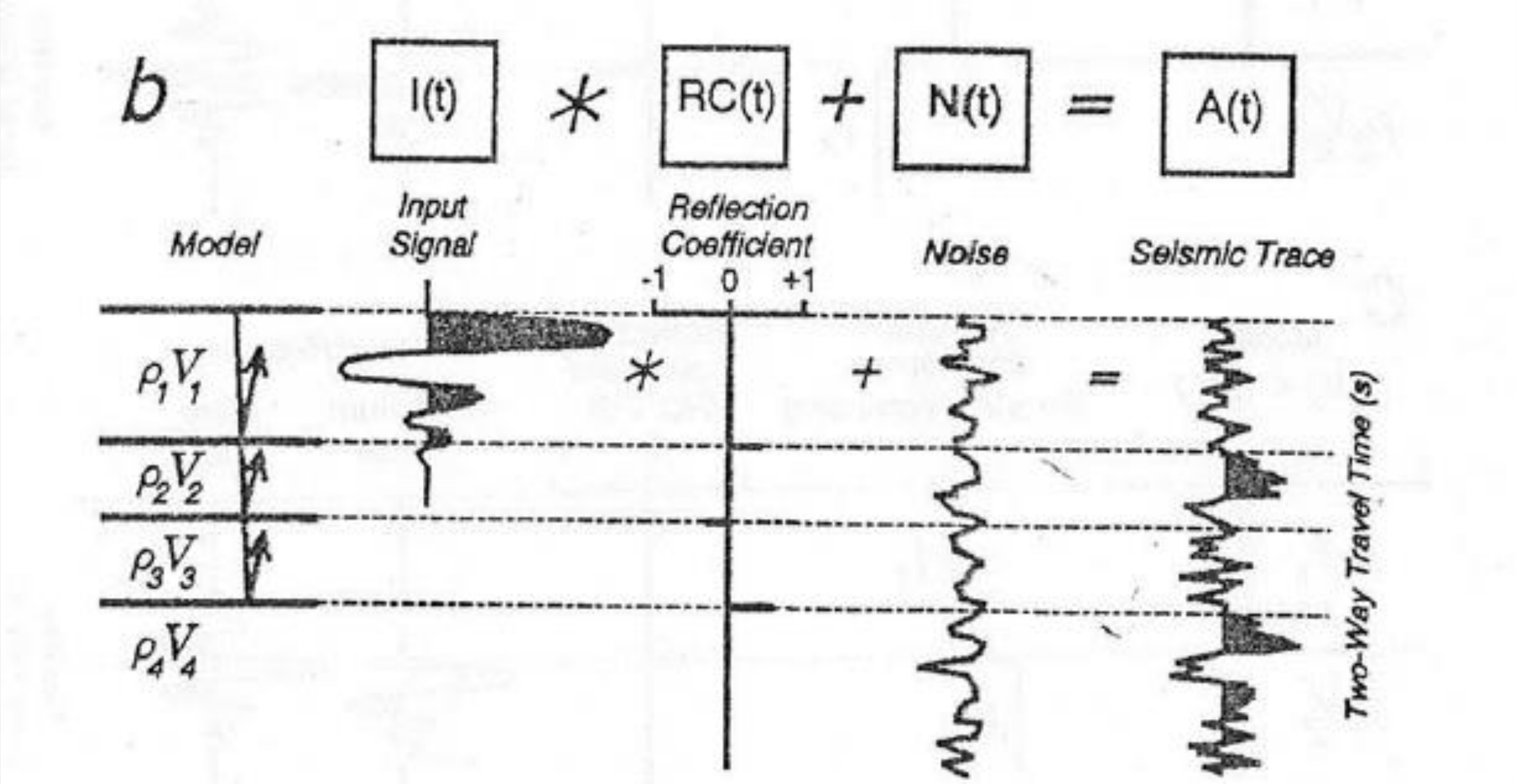
SEISMIC TRACE

- The ability to see stratigraphic change on seismic profiles depend on the amplitude of reflection, relative to the level of noise (signal-to-noise ratio)
- Acquisition and processing technique are designed to filter out noise and keeping the signal resulting from primary reflection, thus enhancing S/N ratio

SEISMIC TRACE



SEISMIC TRACE



SEISMIC TRACE

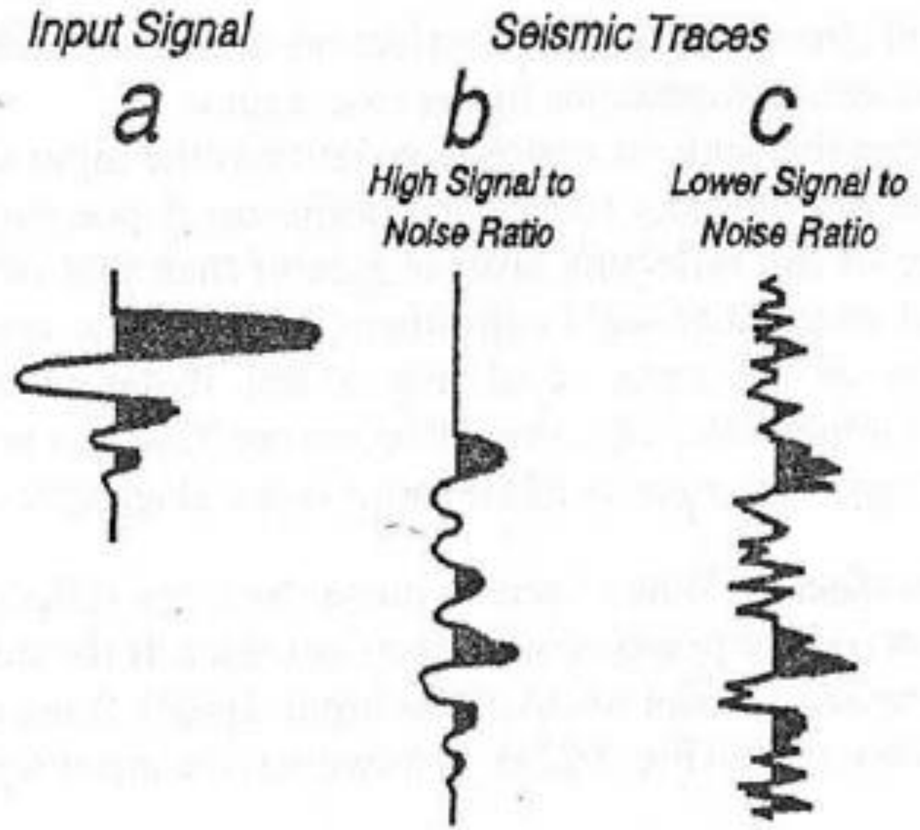


FIGURE 5.29 *Signal-to-noise ratio.* a) Input seismic signal. b) Events mimicking the input signal can be recognized on seismic trace with high signal-to-noise ratio. c) On a trace with low signal-to-noise ratio, seismic events are hidden within the noise.

LET'S WORK WITH COMPUTER

In mathematics, a **Gaussian function**, often simply referred to as a **Gaussian**, is a function of the form:

$$f(x) = a \exp\left(-\frac{(x-b)^2}{2c^2}\right)$$

for arbitrary real constants a, b and c. It is named after the mathematician Carl Friedrich Gauss.

In mathematics and numerical analysis, the **Ricker wavelet**[1]

$$\psi(t) = \frac{1}{\sqrt{2\pi\sigma^3}}\left(1 - \frac{t^2}{\sigma^2}\right) e^{\frac{-t^2}{2\sigma^2}}$$

is the negative normalized second derivative of a Gaussian function, i.e., up to scale and normalization, the second Hermite function. It is a special case of the family of continuous wavelets (wavelets used in a continuous wavelet transform) known as Hermitian wavelets. The Ricker wavelet is frequently employed to model seismic data, and as a broad spectrum source term in computational electrodynamics. It is usually only referred to as the **Mexican hat wavelet** in the Americas, due to taking the shape of a sombrero when used as a 2D image processing kernel. It is also known as the **Marr wavelet** for David Marr.[2][3]