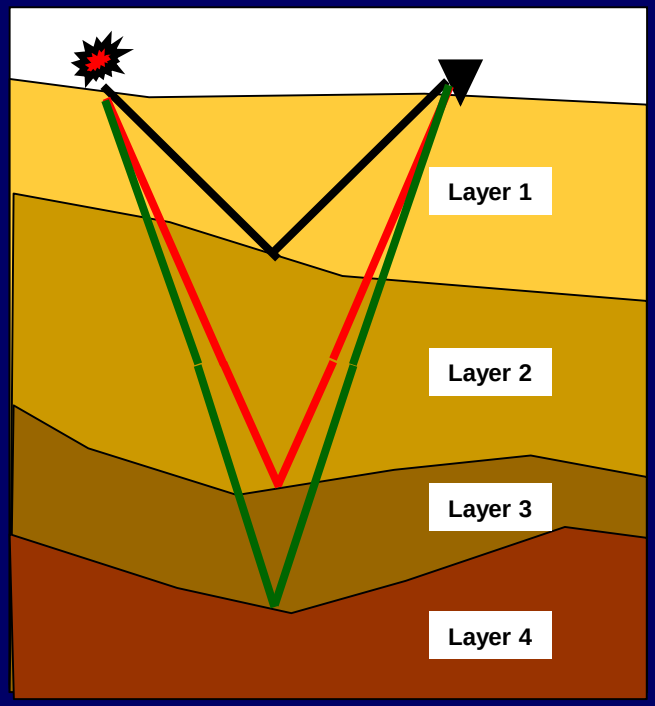
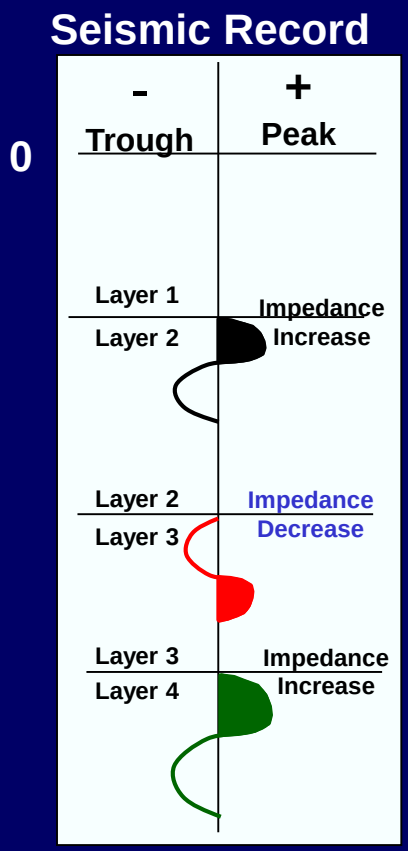
Seismic Reflections



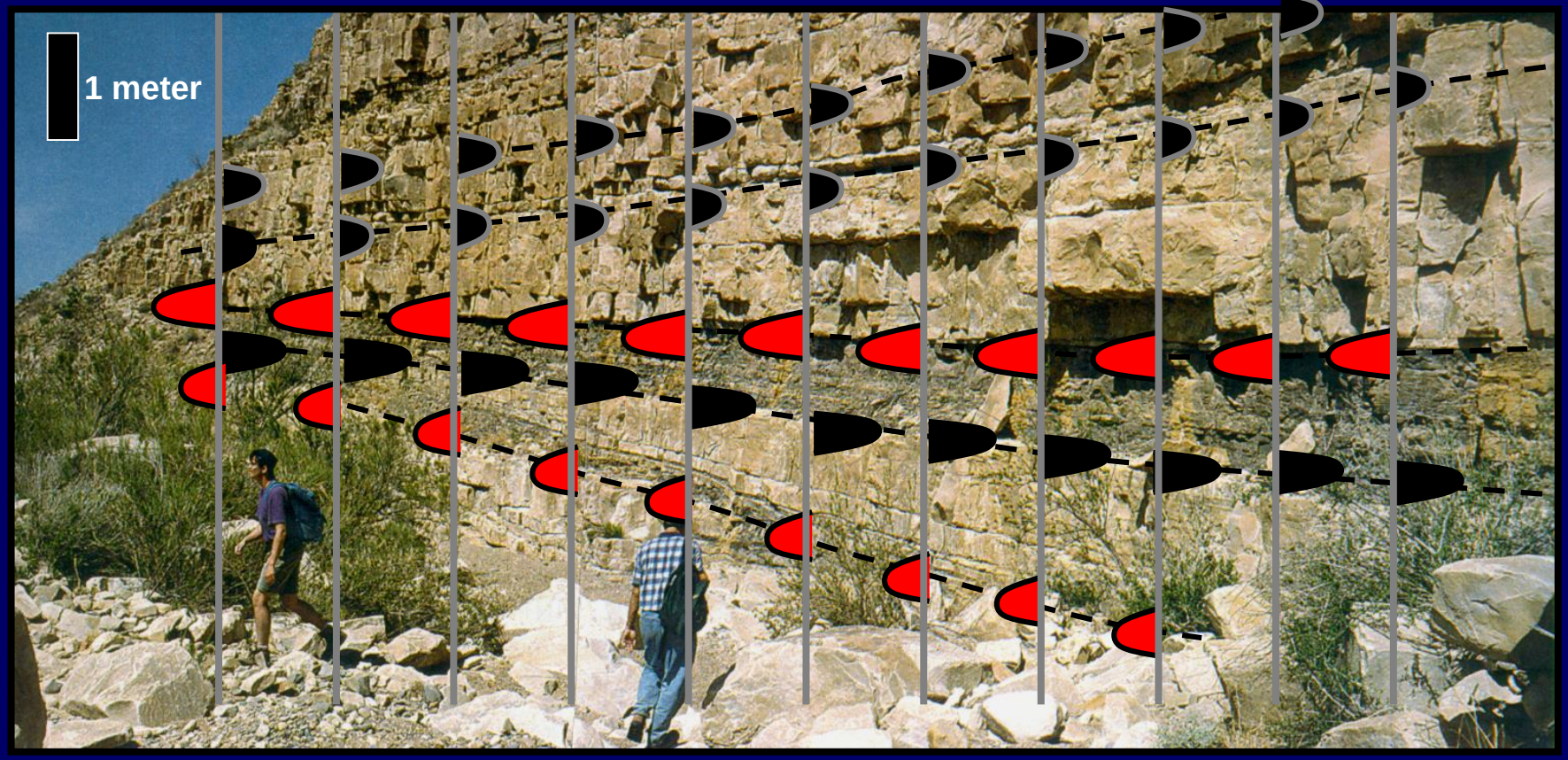
Impedance = Velocity * Density



Peak over Trough is an Increase in Impedance

The Ideal Seismic Response

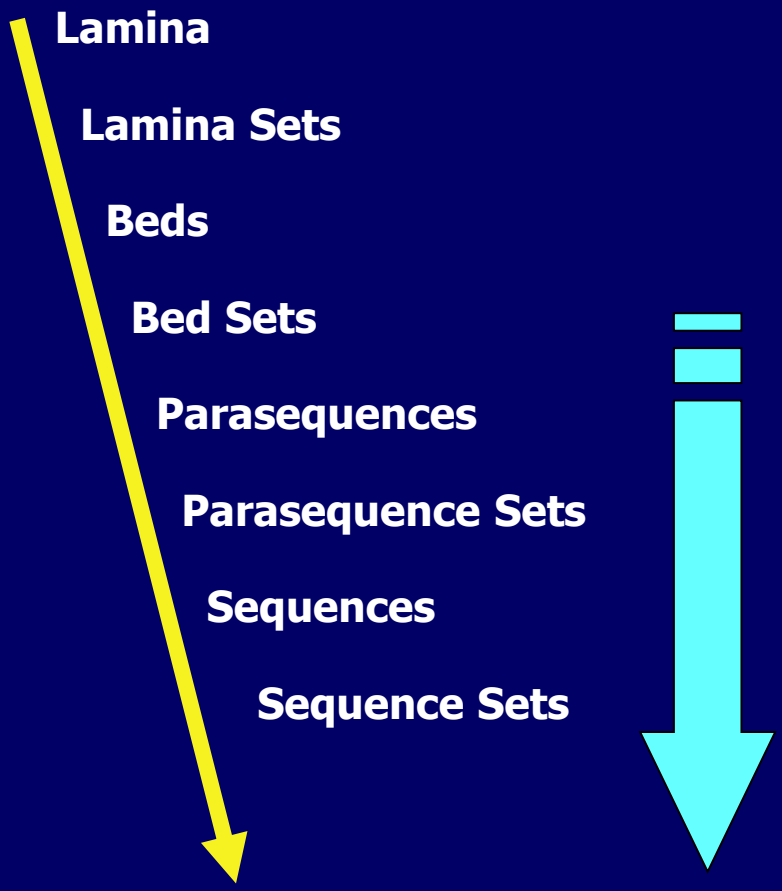
Able to resolve boundaries of beds a few meters thick



 **Increase in Impedance**

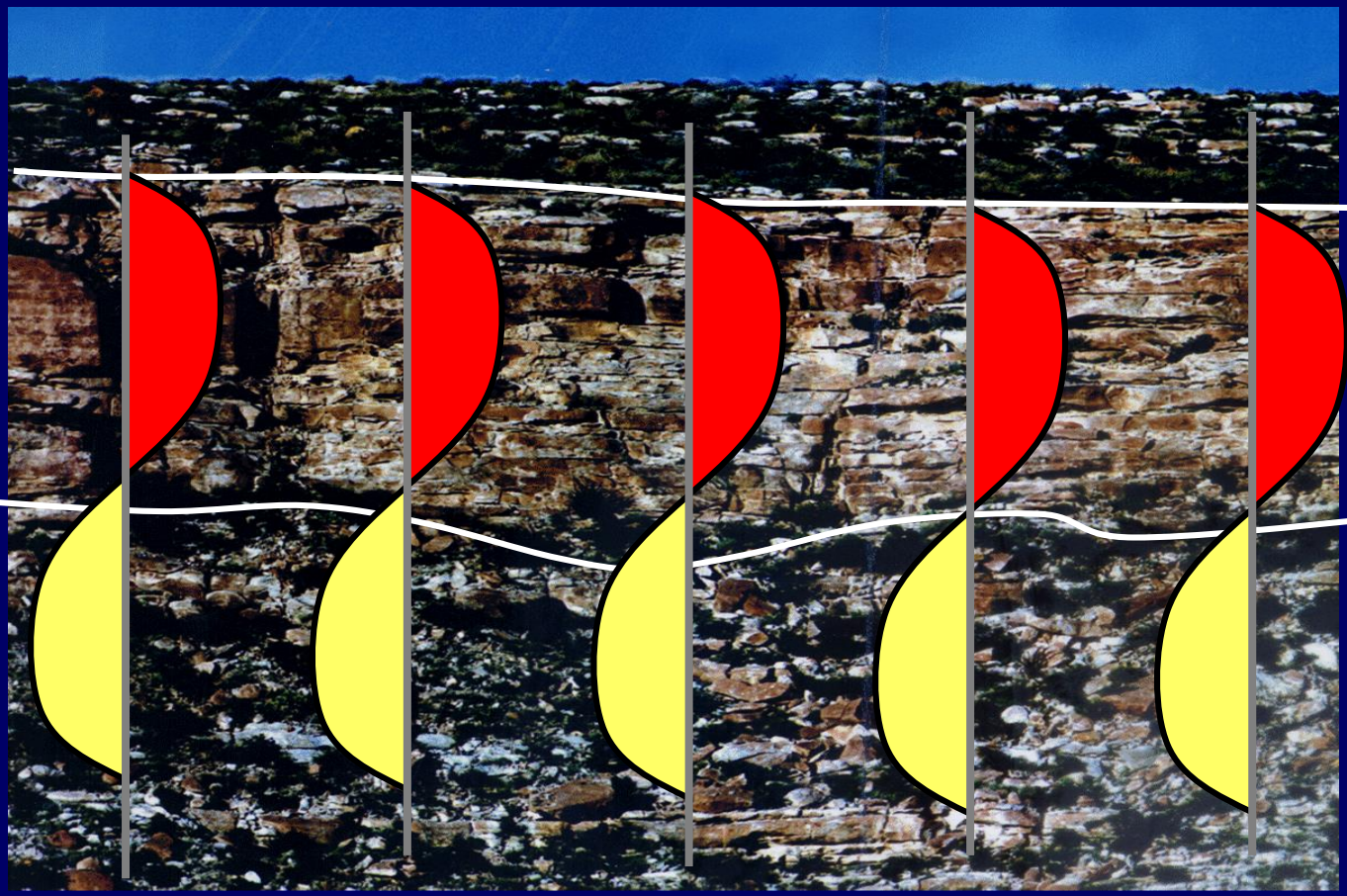
 **Decrease in Impedance**

Scale for Seismic Data



- Although seismic data can not image small-scale stratal units, it can image mid- to large-scale units
- The big advantage of seismic data is areal coverage

Seismic - Units 10s of Meters Thick



Mainly
Shale

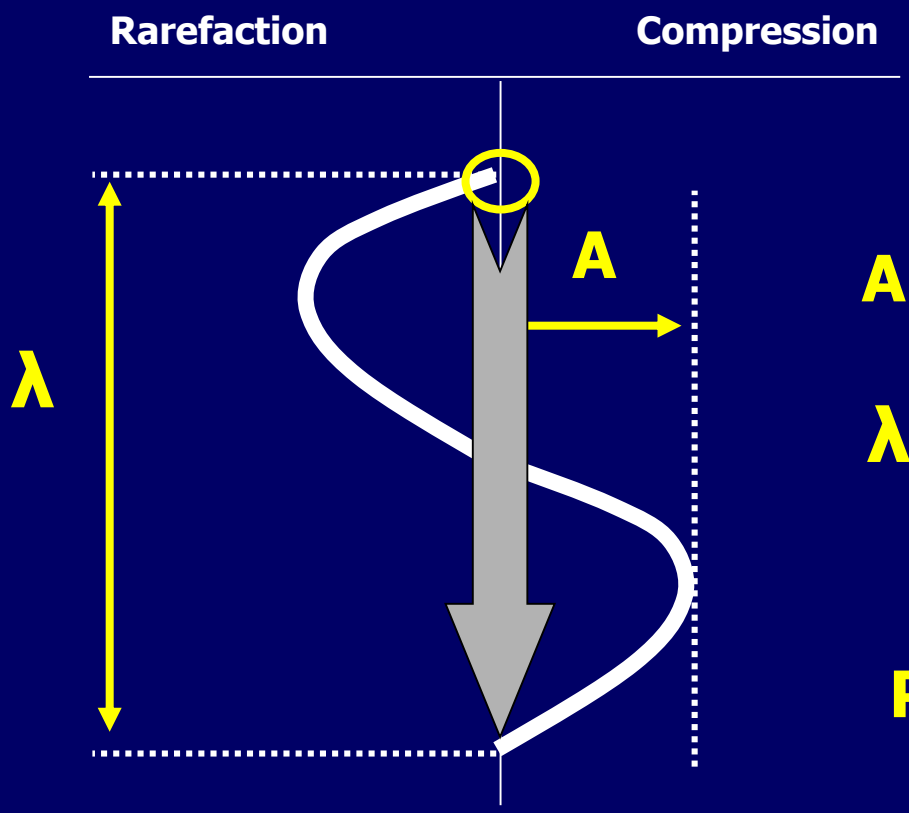
Mainly
Sand

Mainly
Shale

10 m

Courtesy of ExxonMobil

Wave Equation Lingo



A = Amplitude

λ = Wavelength

length, ft or m

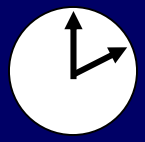
P = Period

time

D_p = Pulse Duration

time

Period = Time for the waveform to travel 1 wavelength



Basic Equations

1. $P = 1 / f$

2. $\lambda = V * P = V / f$

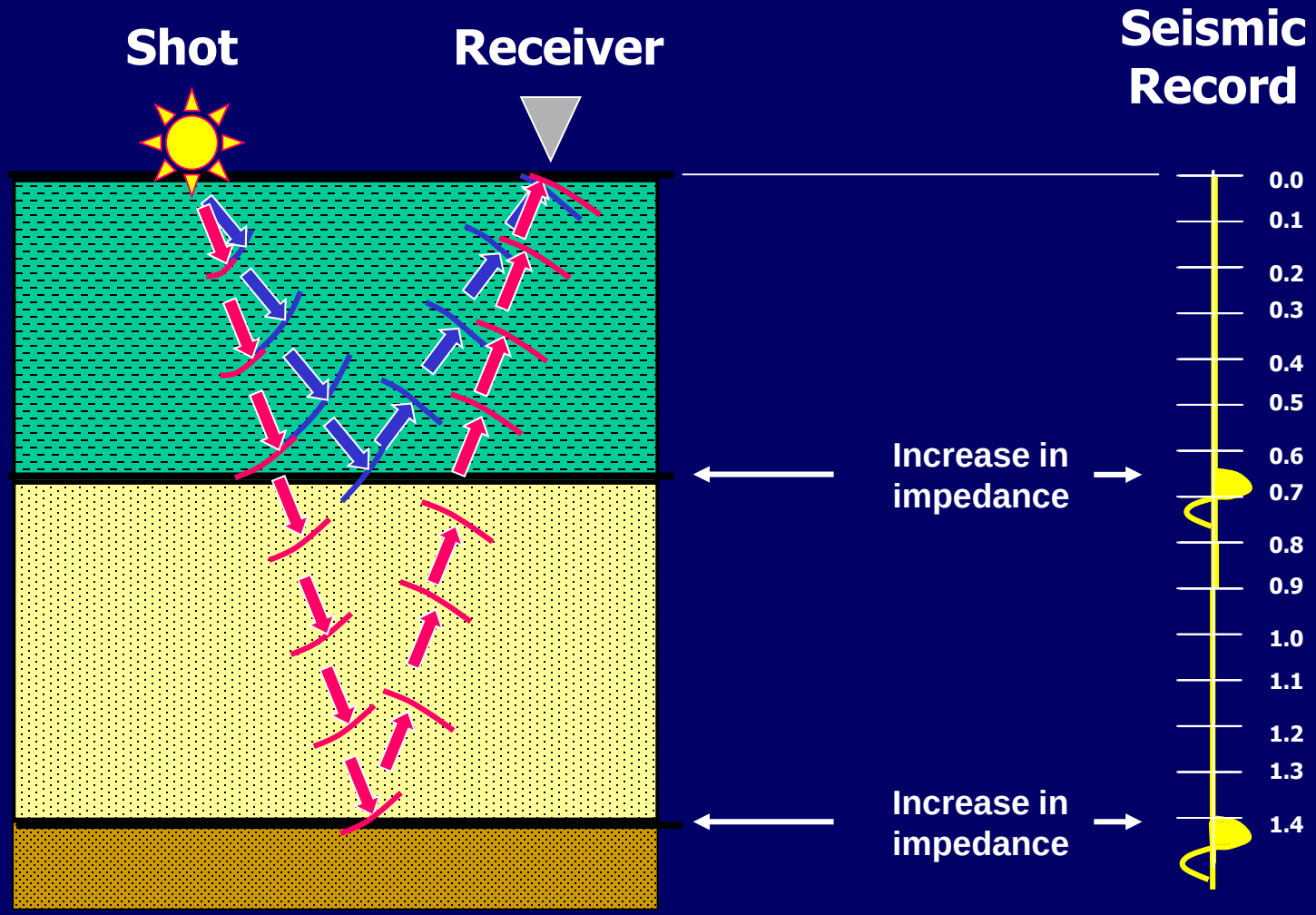
3. $d = V * T / 2$

where

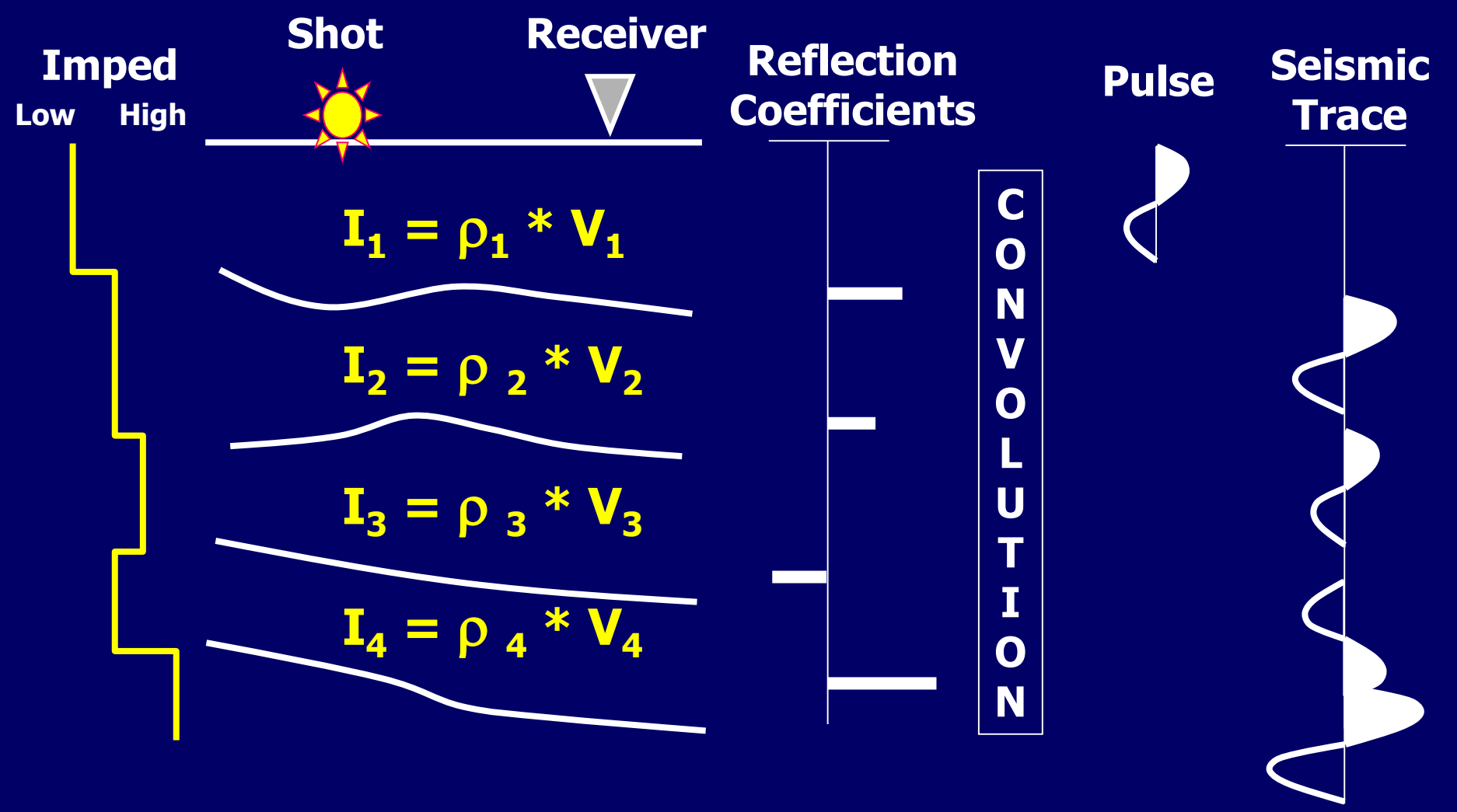
P = Period	V = Velocity
f = Frequency	d = distance (depth)
λ = Wavelength	T = time

Back to Basics

Seismic energy travels down and is reflected off acoustic boundaries



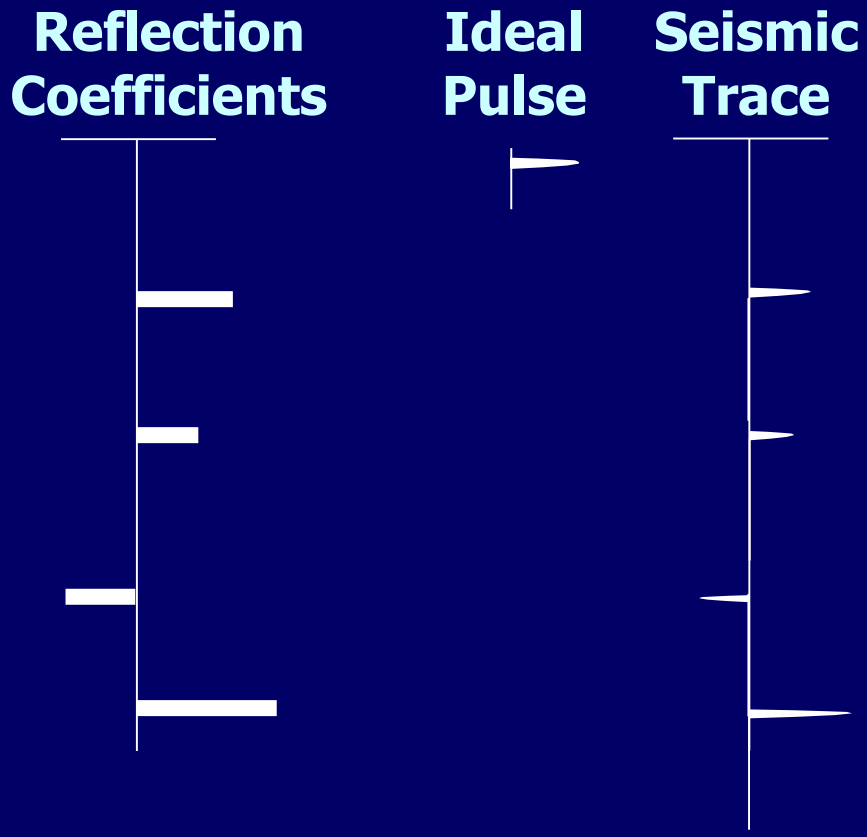
Acoustic Structure of the Earth

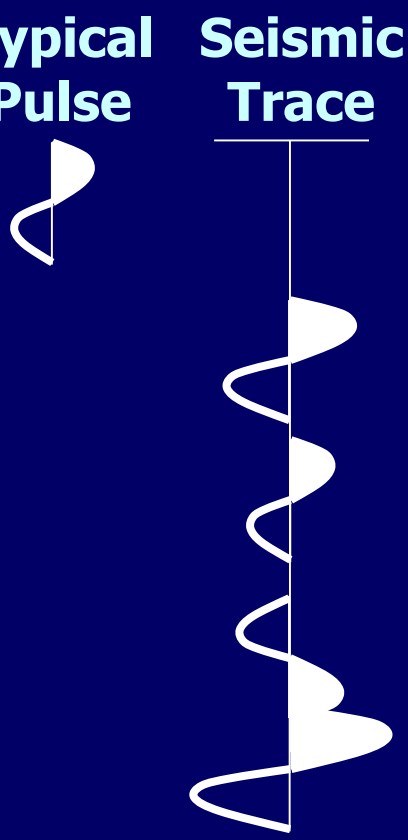


That 'Pesky' Pulse

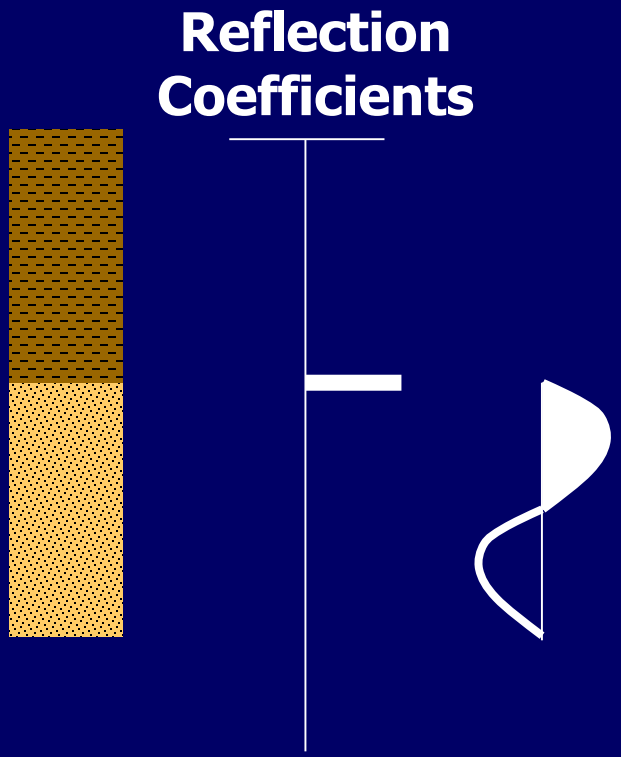
If the frequency content (Bandwidth) is very large, then the pulse approaches a spike and we can resolve fine-scale stratigraphy

Typically the frequency content is limited to about 10 to 50 Hz (BW = 40), which limits our resolution





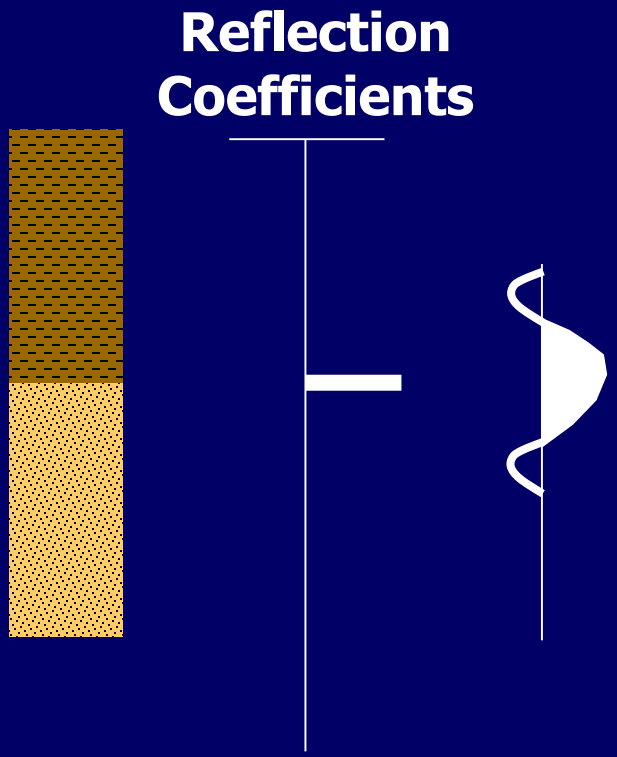
Types of Pulses



Minimum Phase

- Causal (real – no motion before wave arrives)
- Front loaded
- Peak arrival time is frequency dependent
- RC is at the first displacement; maximum displacement (peak or trough) is delayed by ¼ λ

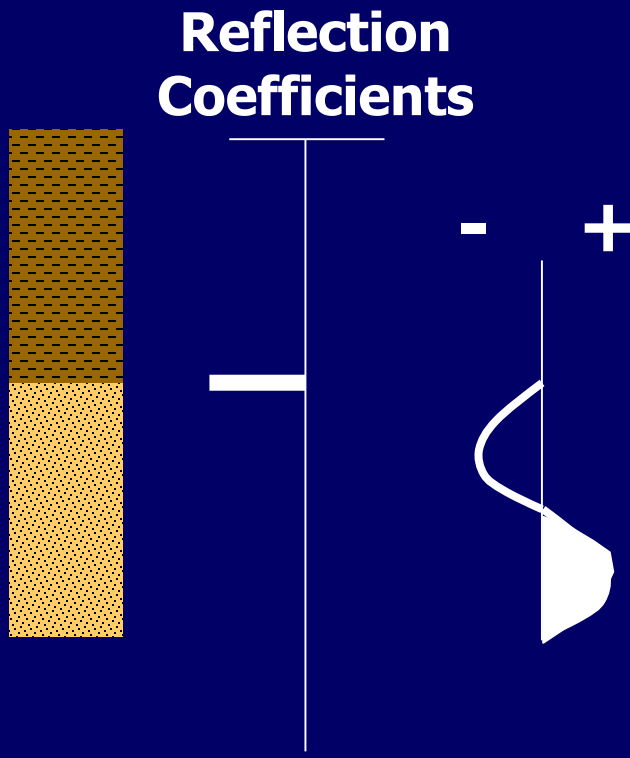
Types of Pulses



Zero Phase

- Not Causal (not real, since there is motion before the wave arrives)
- Symmetric about RC
- Peak arrival time is not frequency dependent
- Maximum peak-to-side lobe ratio
- RC is at the maximum displacement (peak or trough)

Polarity – Minimum Phase



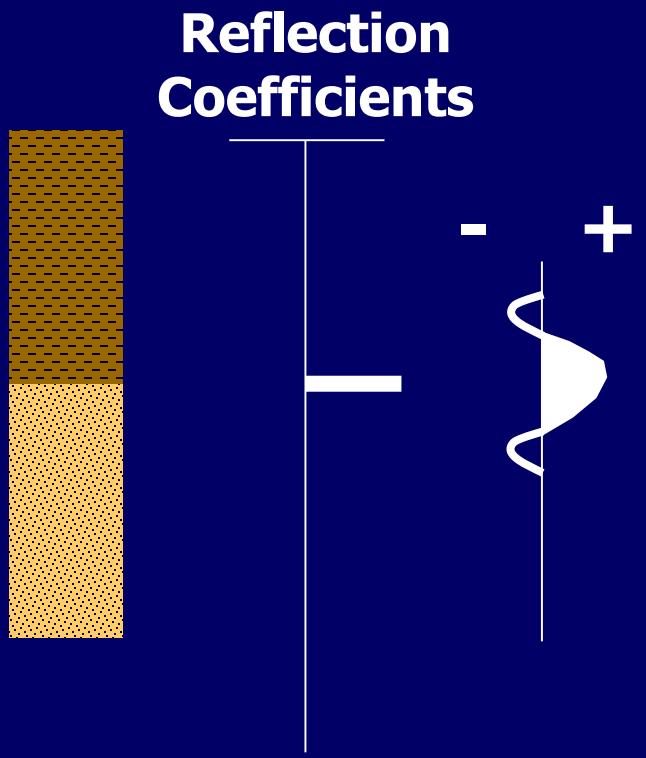
SEG Normal Convention

A compression is:

- Negative # on the tape
- Displayed as a Trough

SEG = Society of Exploration Geophysics

Polarity – Zero Phase



SEG Normal Convention

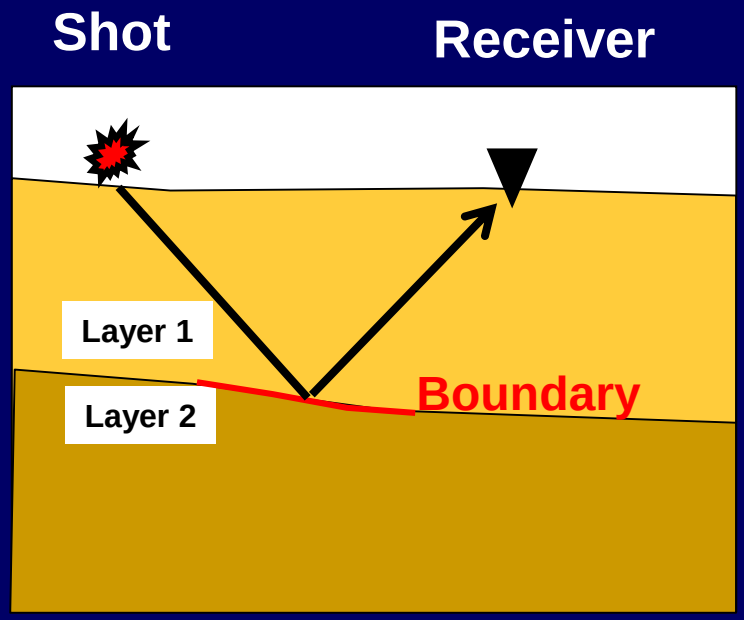
A compression is:

- Positive # on the tape
- Displayed as a Peak

SEG = Society of Exploration Geophysics

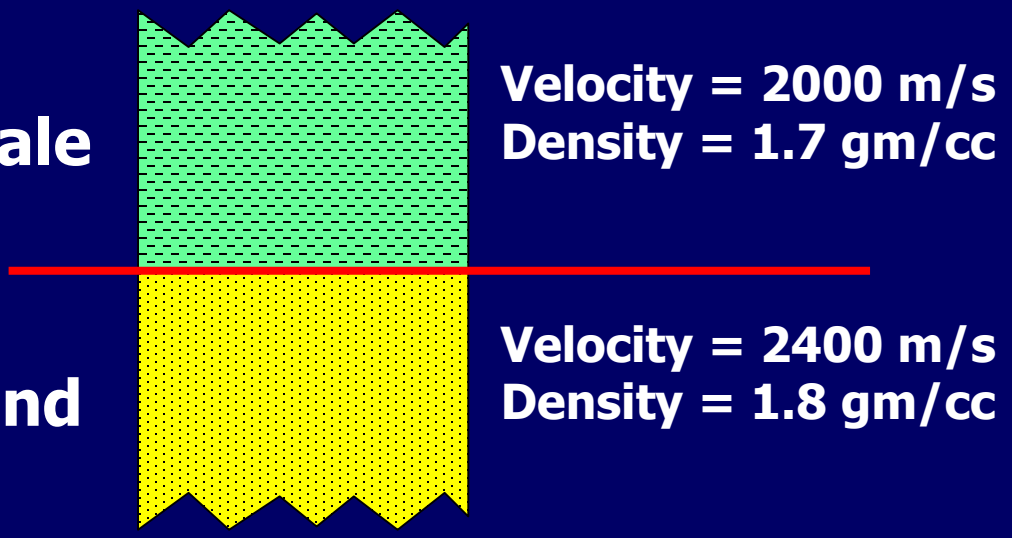
What Causes Reflections?

- **Any interface between bodies with different acoustic properties**
- **Acoustic properties define Impedance (I) , in which**
  I = velocity * density



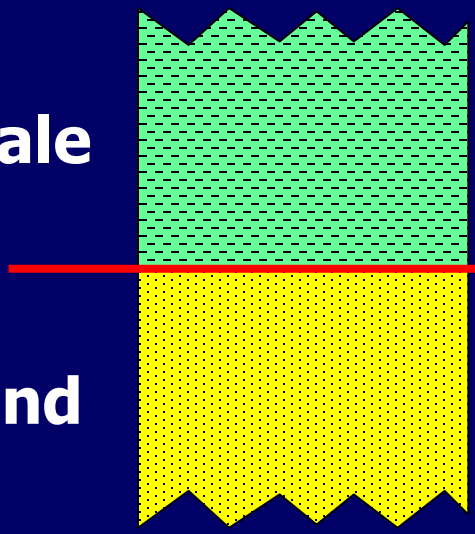
- Small change in impedance – small reflection
- Large change in impedance – large reflection

Seismic Interface



$$\text{Reflection Coefficient} = \frac{I_{below} - I_{above}}{I_{below} + I_{above}} = \frac{\qquad\qquad}{\qquad\qquad} =$$

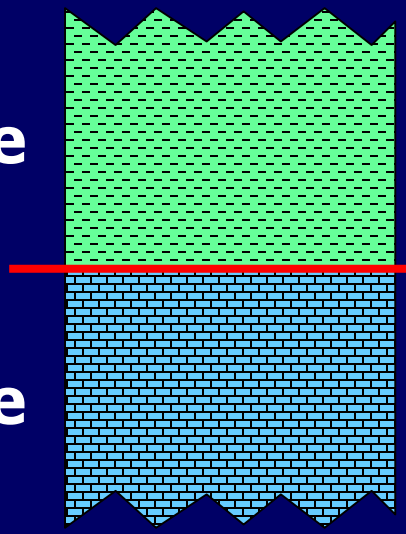
Seismic Interface



$$\text{Reflection Coefficient} = \frac{I_{below} - I_{above}}{I_{below} + I_{above}} = \frac{4320 - 3400}{4300 + 3400} = 0.119$$

Of the incident energy, 12% is reflected, 88% is transmitted

Seismic Interface



Shale

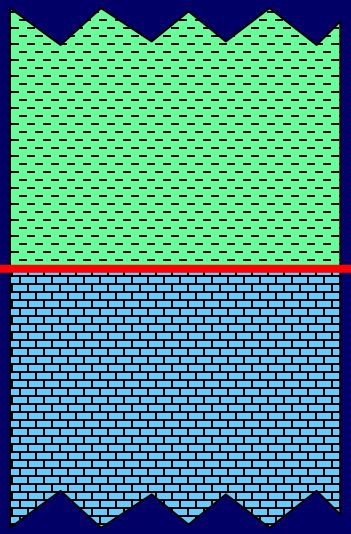
Velocity = 2000 m/s
Density = 1.7 gm/cc

Carbonate

Velocity = 2600 m/s
Density = 2.1 gm/cc

$$\text{Reflection Coefficient} = \frac{I_{below} - I_{above}}{I_{below} + I_{above}} = \frac{\qquad\qquad}{\qquad\qquad} =$$

Seismic Interface



Shale

Velocity = 2000 m/s
Density = 1.7 gm/cc
I = 2000 * 1.7 = 3400

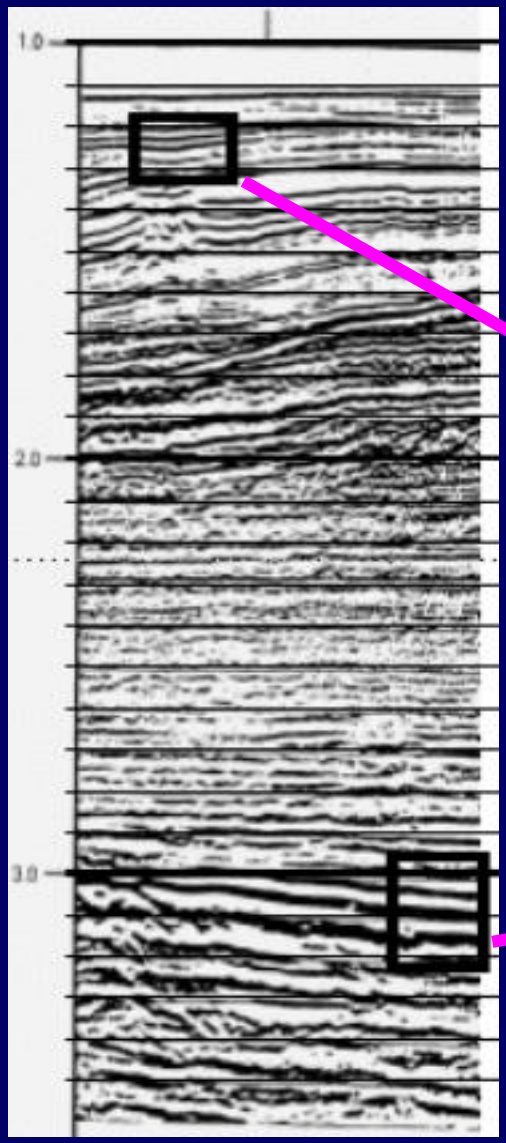
Carbonate

Velocity = 2600 m/s
Density = 2.1 gm/cc
I = 2600 * 2.1 = 5460

$$\text{Reflection Coefficient} = \frac{I_{below} - I_{above}}{I_{below} + I_{above}} = \frac{5460 - 3400}{5460 + 3400} = 0.232$$

Of the incident energy, 23% is reflected, 77% is transmitted

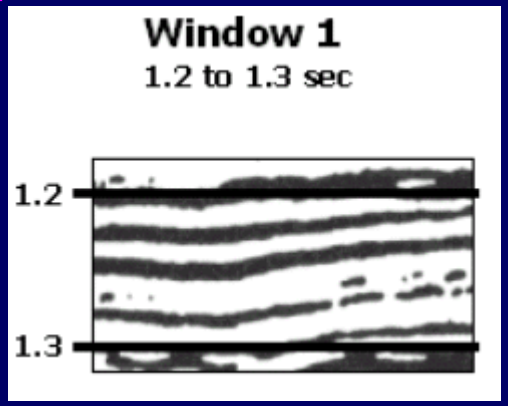
Exercise 6b: Frequency & Wavelength

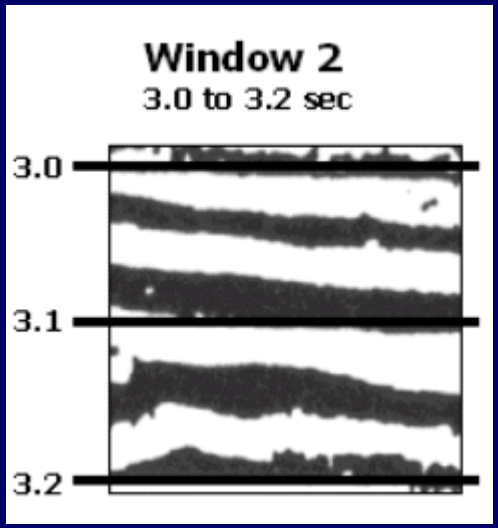


$F_{apparent}$ = # cycle / time interval

$F_{dominant} = (2 * F_{apparent}) / \pi$

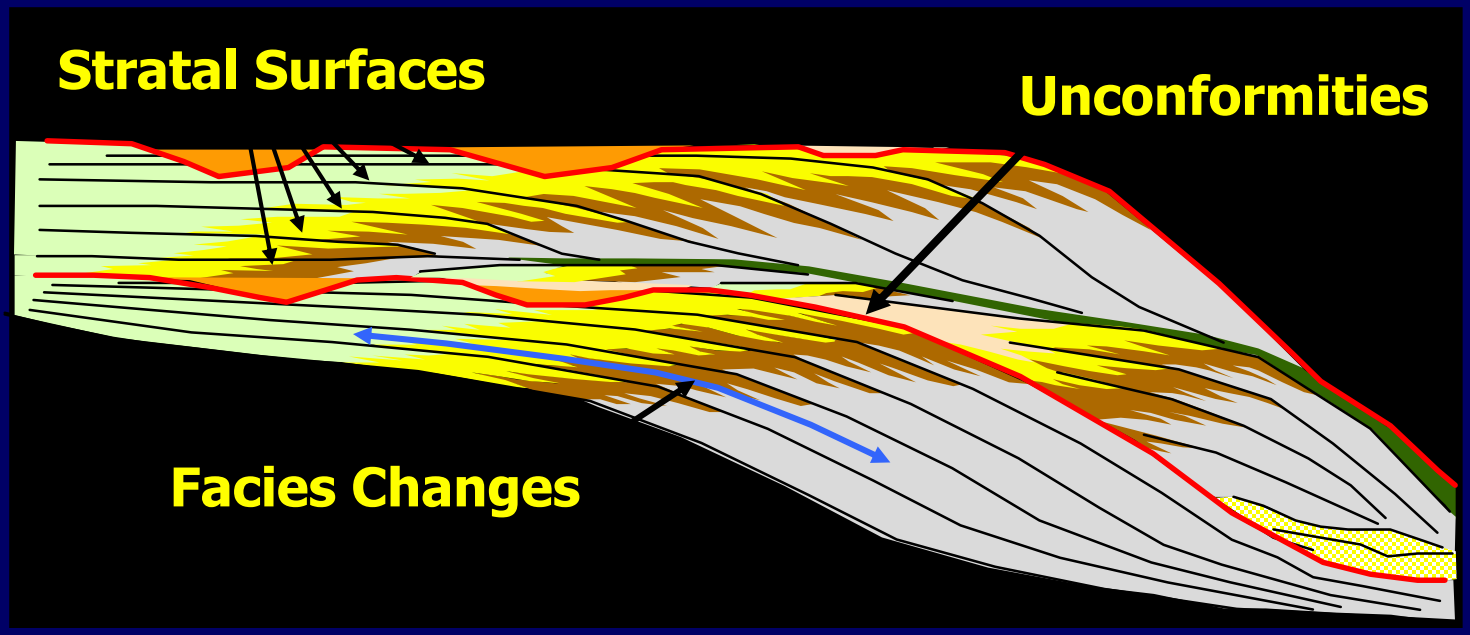
λ = Velocity / $F_{dominant}$





Seismic Data & Stratal Surfaces

- Seismic reflections parallel stratal surfaces
- Reflection terminations mark unconformities
- Changes in reflection character indicate facies changes



Fluvial Incised Valley Fill
Coastal Plain
Foreshore/Upper Shoreface
Lower Shoreface - Offshore
Slope - Basin
Submarine Fan
Estuarine
Condensed Interval

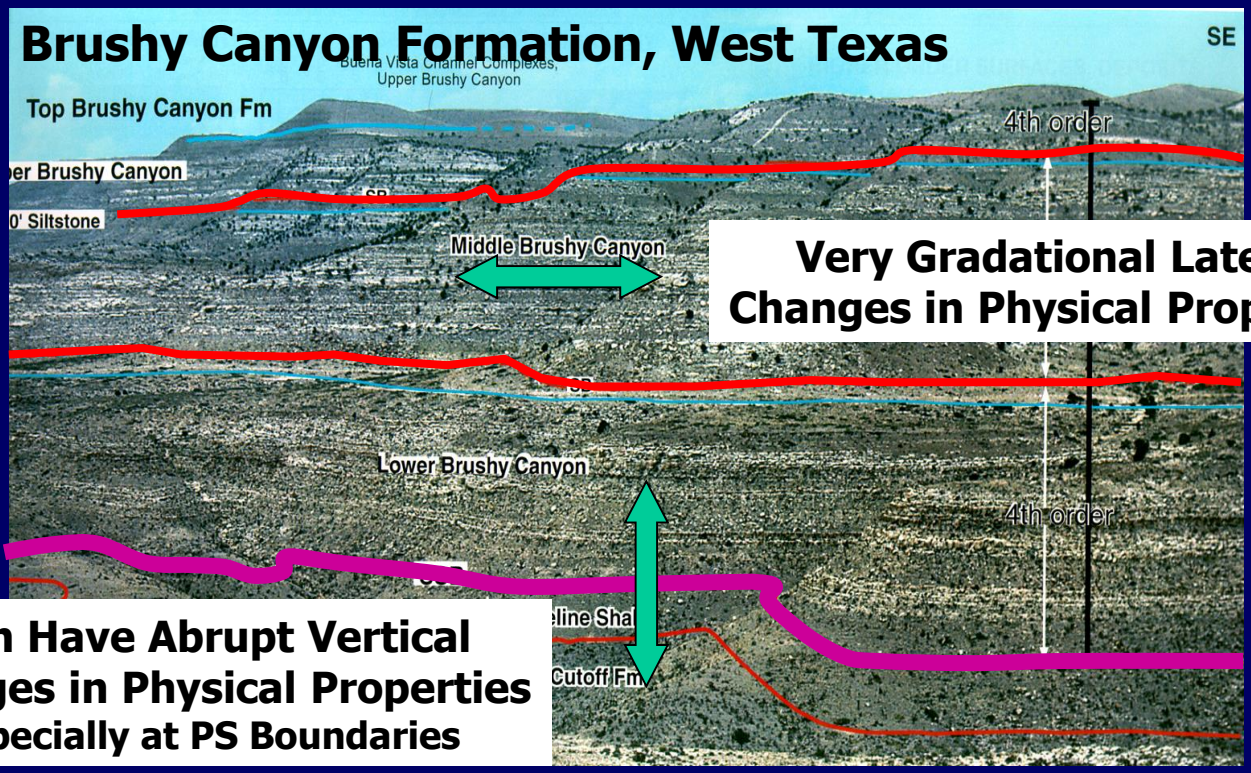
Courtesy of ExxonMobil

Why Stratal Surfaces?

Recall: Reflections are generated where there is a change in acoustic properties ($I = \rho v$)

Consider: Where can there be sharp changes in impedance?

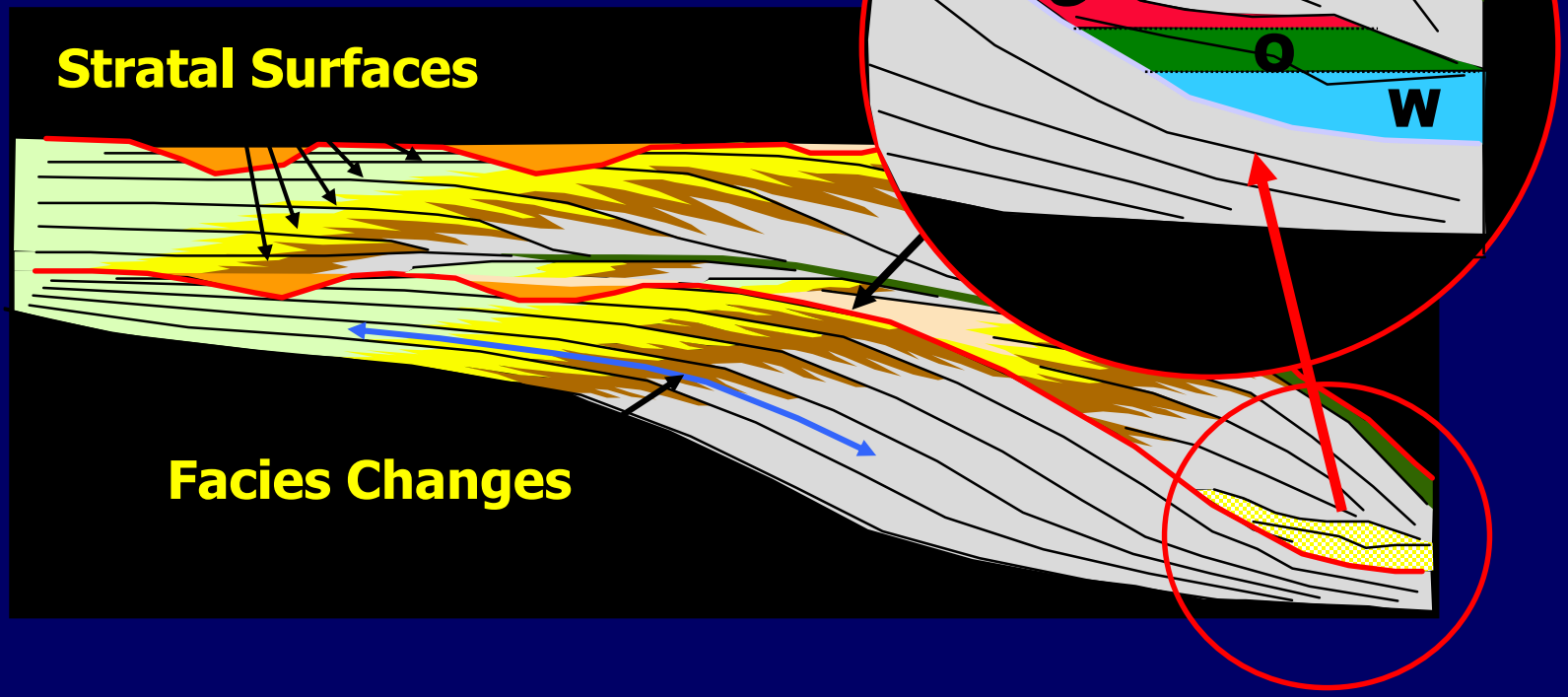
- **horizontally as lithofacies change?**
- **vertically across stratal boundaries?**



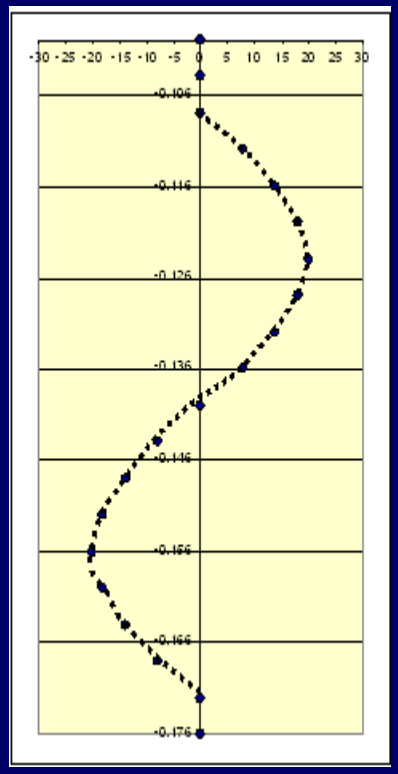
Not Every Reflection is Strata!

There are other seismic reflections out there that may not be stratigraphic in origin

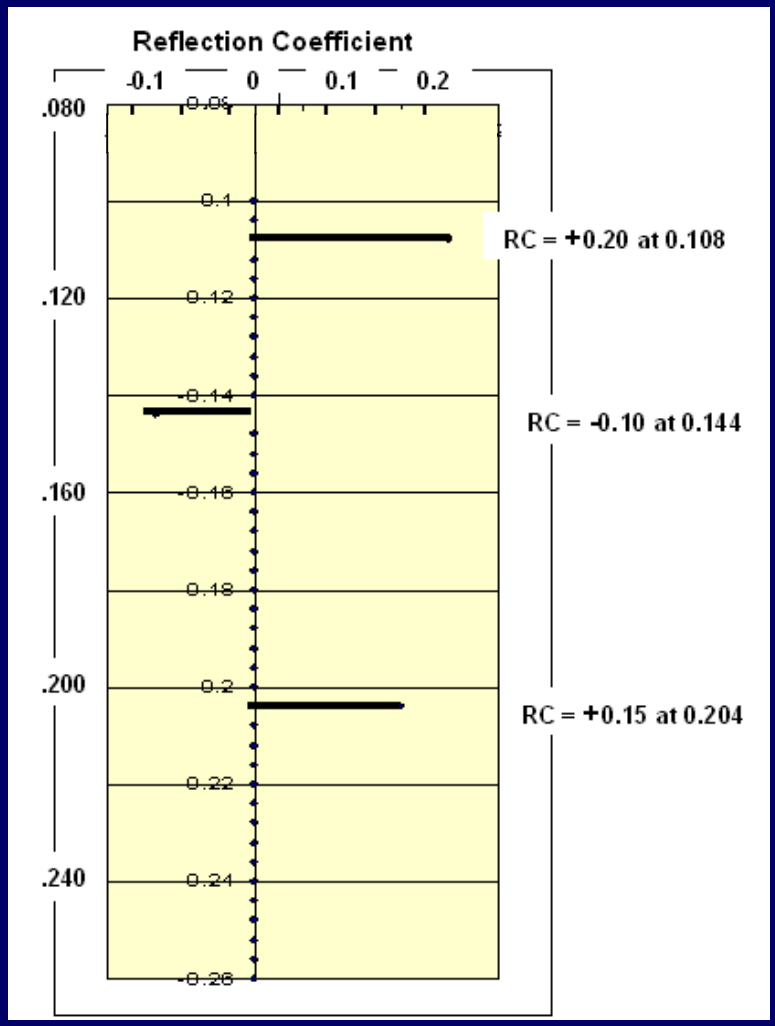
- Fluid Contacts
- Fault Planes
- Multiples
- Others



Exercise 6c: A Synthetic Trace



The Pulse



3 Ref. Coeff.