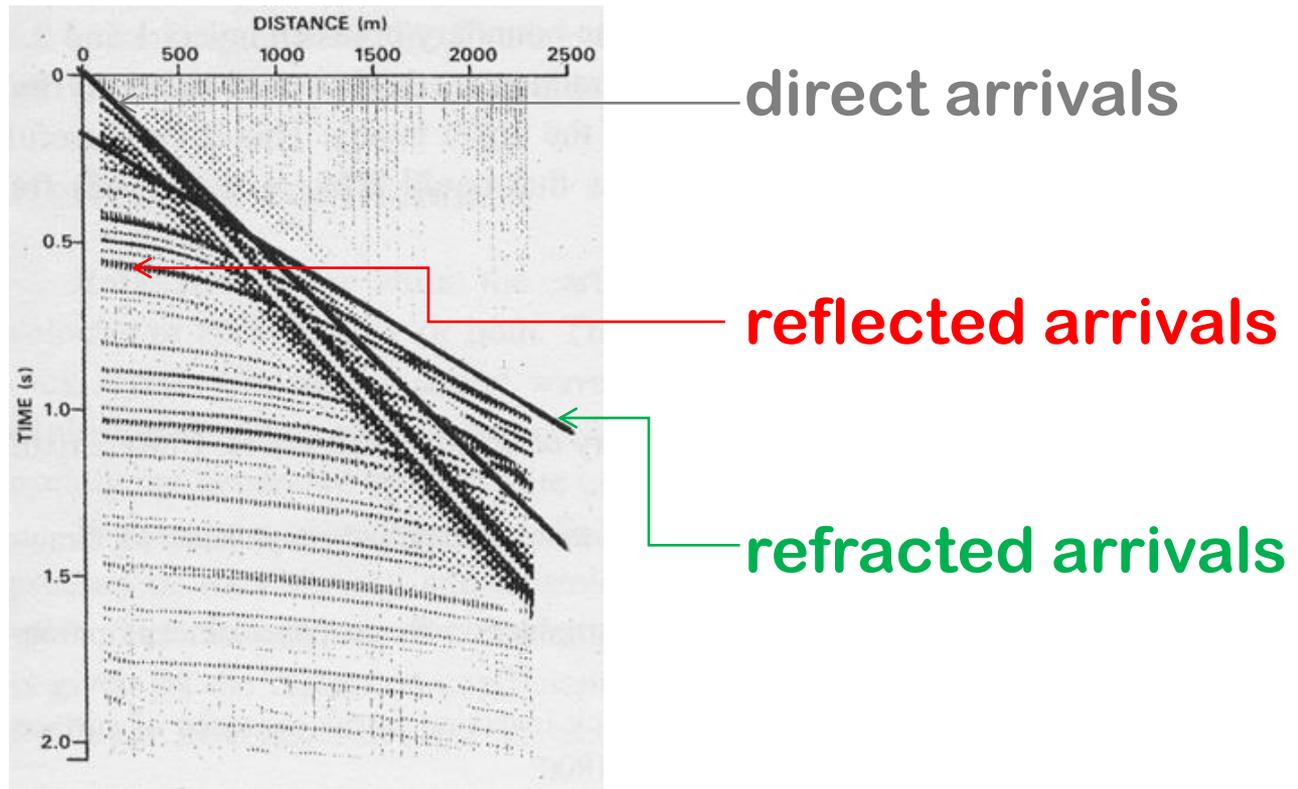


# Assunzioni Geofisiche di Base



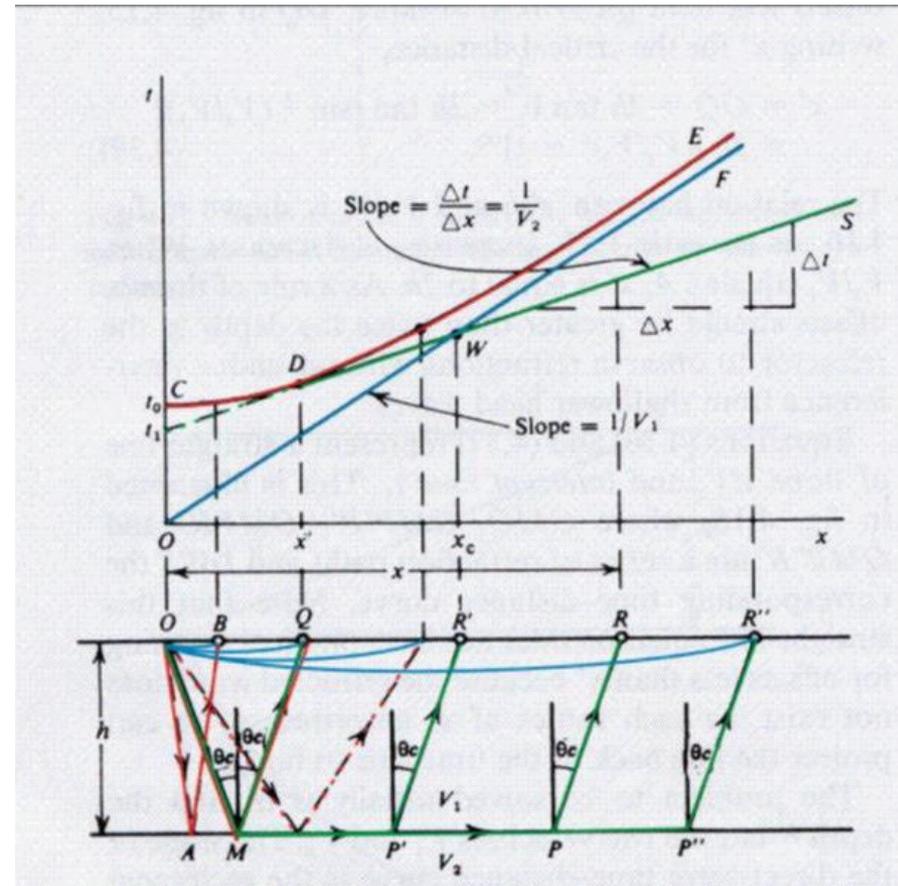
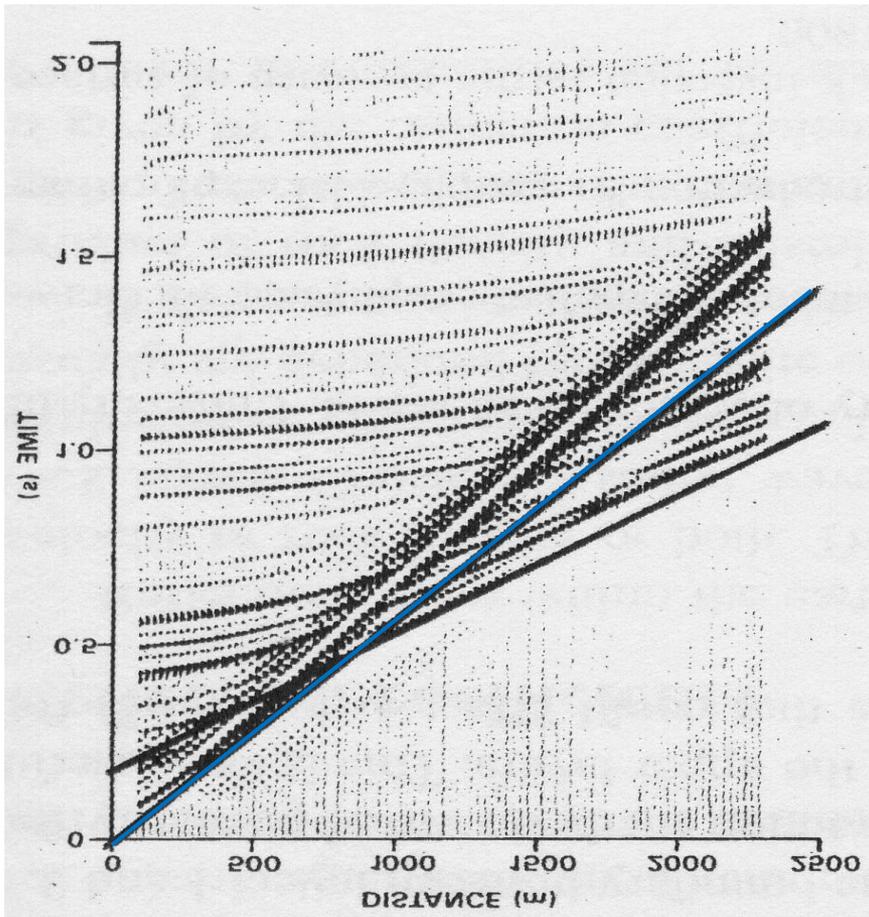


Fig. 4.15 Relation between reflection and refraction raypaths and traveltime curves.

**T = tempo di arrivo**

**x = distanza sorgente-ricevitore (*offset*)**

**V<sub>1</sub> = velocità onde P nello strato superiore**

Onda diretta      $T = \frac{x}{V_1}$

Onda rifratta

$$T = \frac{x}{v_2} + \frac{2h \cos i_c}{v_1}$$

Legge di Snell

$$\frac{\sin \theta_1}{v_1} = \frac{\sin \theta_2}{v_2} = p.$$

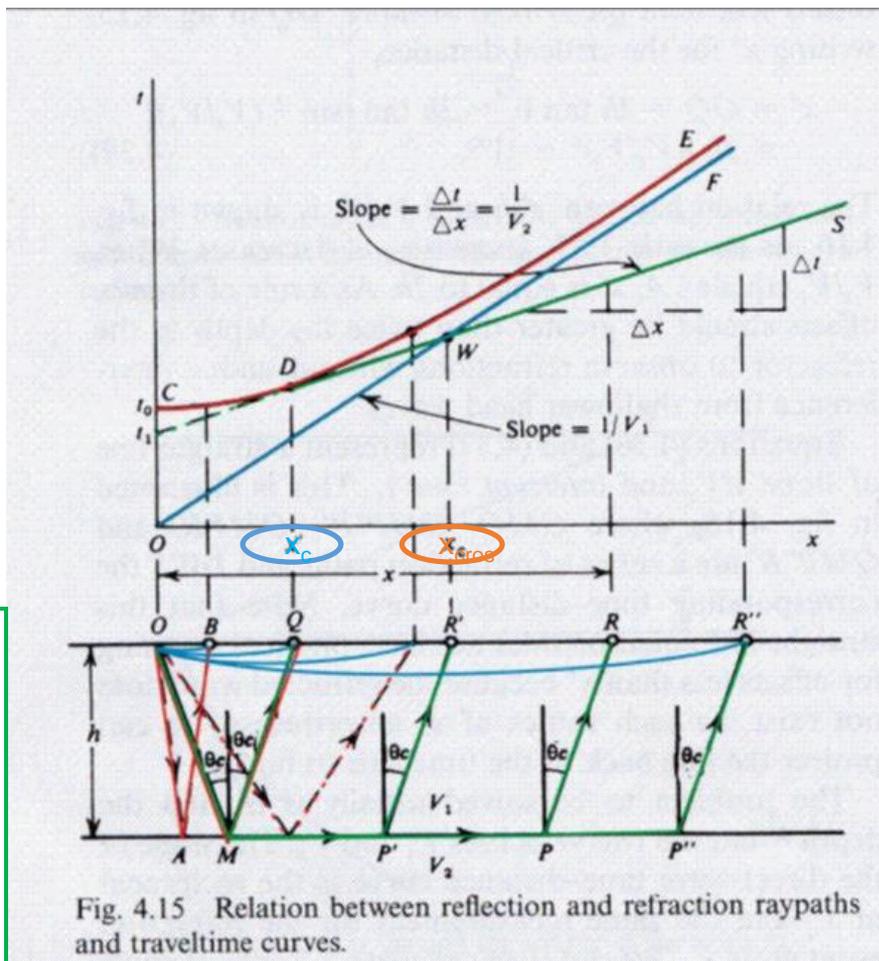
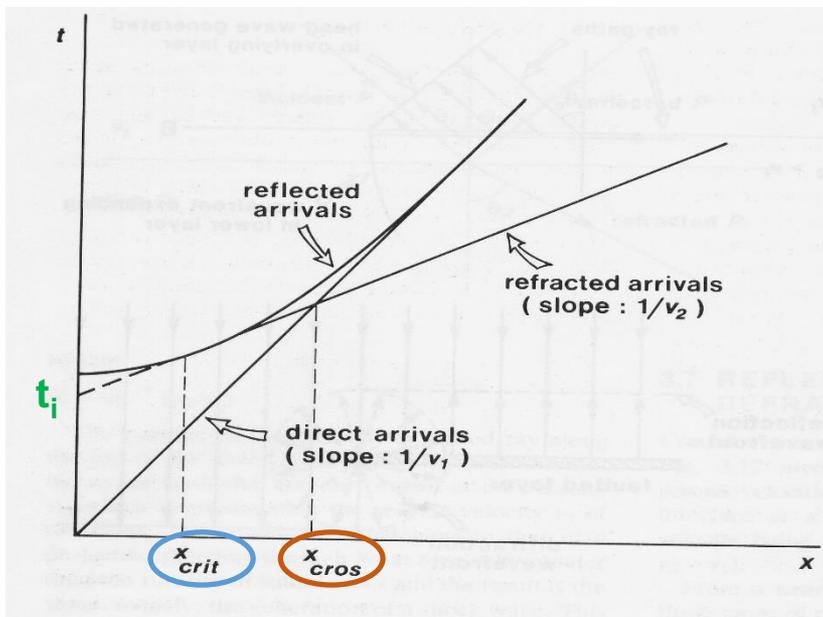
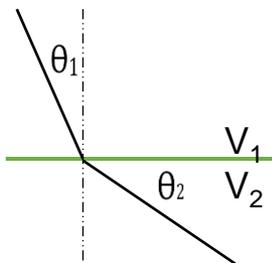


Fig. 4.15 Relation between reflection and refraction raypaths and traveltime curves.

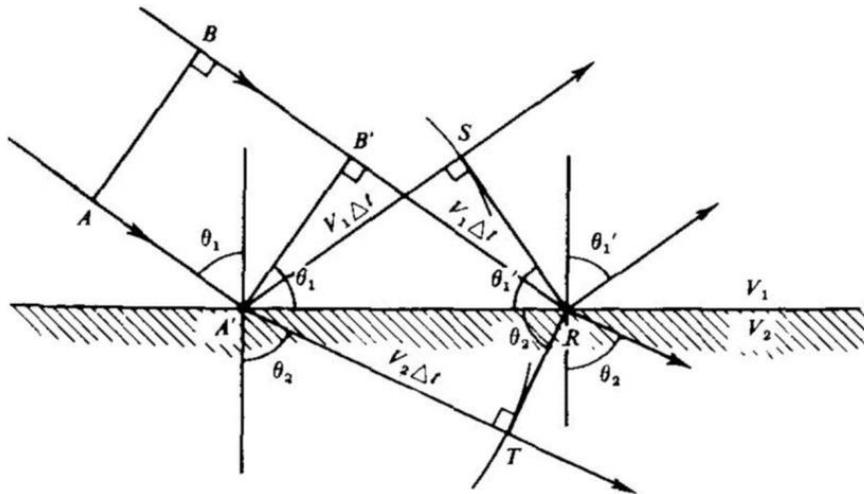
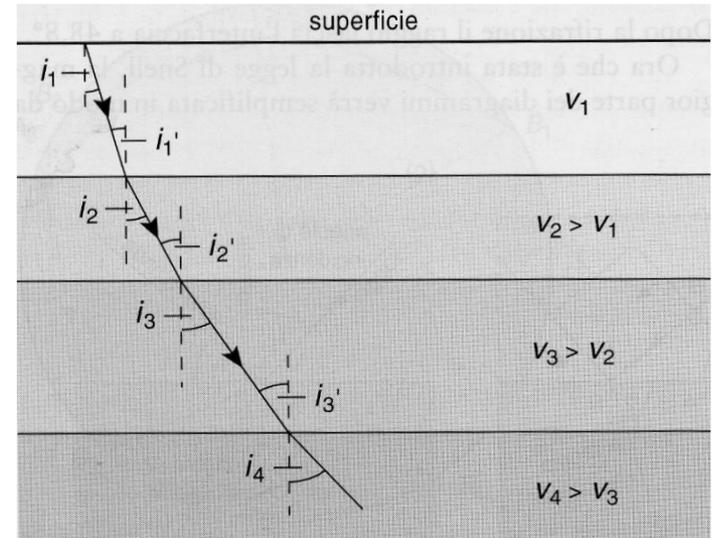
$t_i$  = tempo intercetto

$x_c$  o  $x_{crit}$  = distanza critica

$x_{cros}$  = distanza di crossover

# Onde rifratte

La sismica a rifrazione utilizza le onde rifratte originate da onde incidenti con angolo d'incidenza pari all'angolo critico  $i_c \rightarrow$  angolo di rifrazione pari a  $90^\circ$



Reflection and refraction of a plane wave.

In sismica a riflessione, il fenomeno della rifrazione è molto importante: in corrispondenza delle discontinuità la maggior parte di energia viene trasmessa in profondità attraverso rifrazione delle onde P

# Principio di Huygens

Ogni punto di un fronte d'onda può essere pensato come una sorgente puntiforme di onde con stessa fase.

La figura di interferenza (involuppo) ottenuta dall'insieme delle onde sferiche costituisce il nuovo fronte dell'onda avanzante.

Le riflessioni possono essere viste come conseguenza del Principio di Huygens

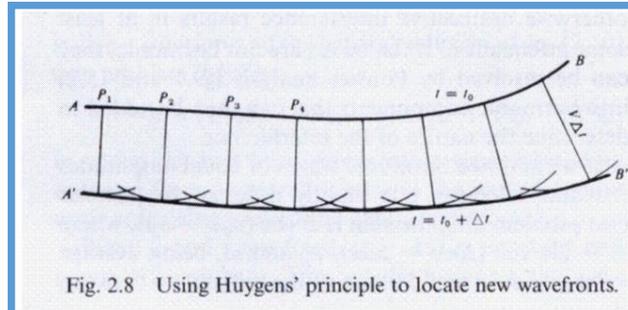


Fig. 2.8 Using Huygens' principle to locate new wavefronts.

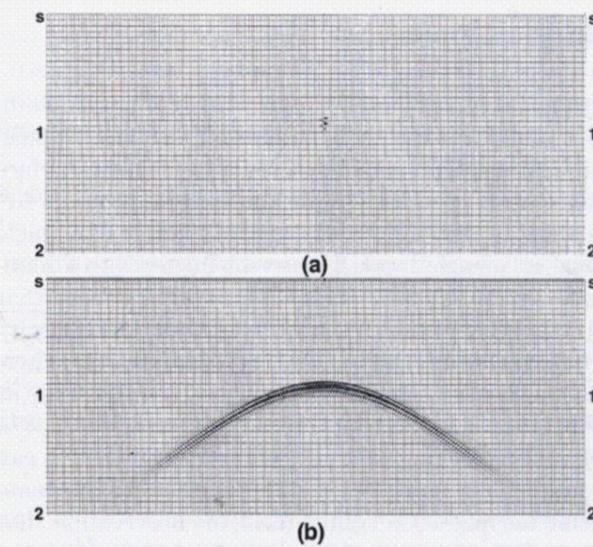


FIG. 4.1-11. A point that represents a Huygens' secondary source (a) produces a diffraction hyperbola on the zero-offset time section (b). The vertical axis in this section is two-way time

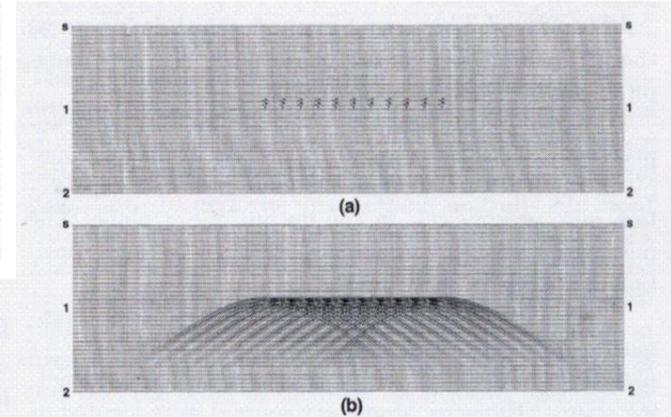


FIG. 4.1-12. Superposition of the zero-offset responses (b) of a discrete number of Huygens' secondary sources as in (a).

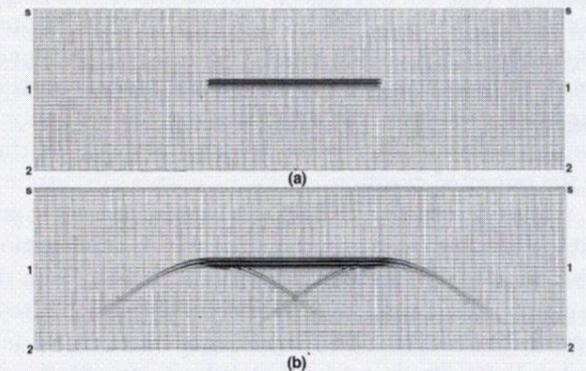
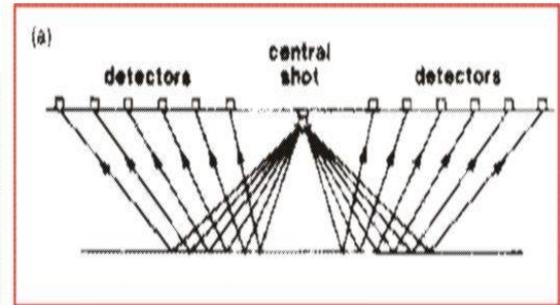
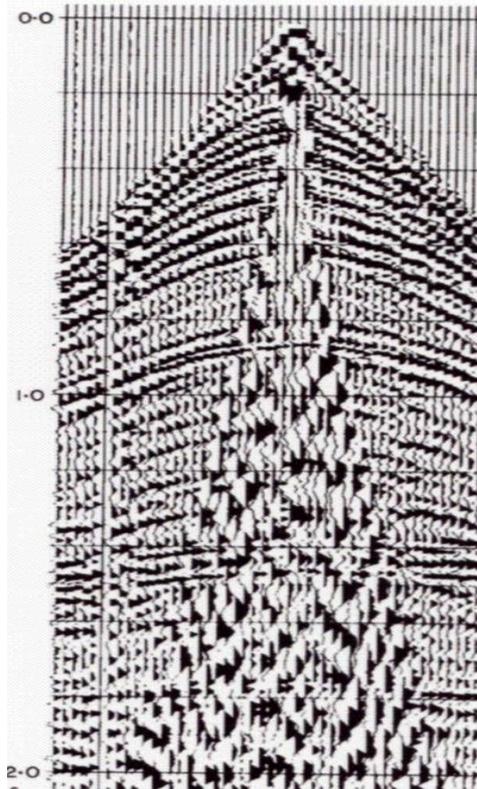
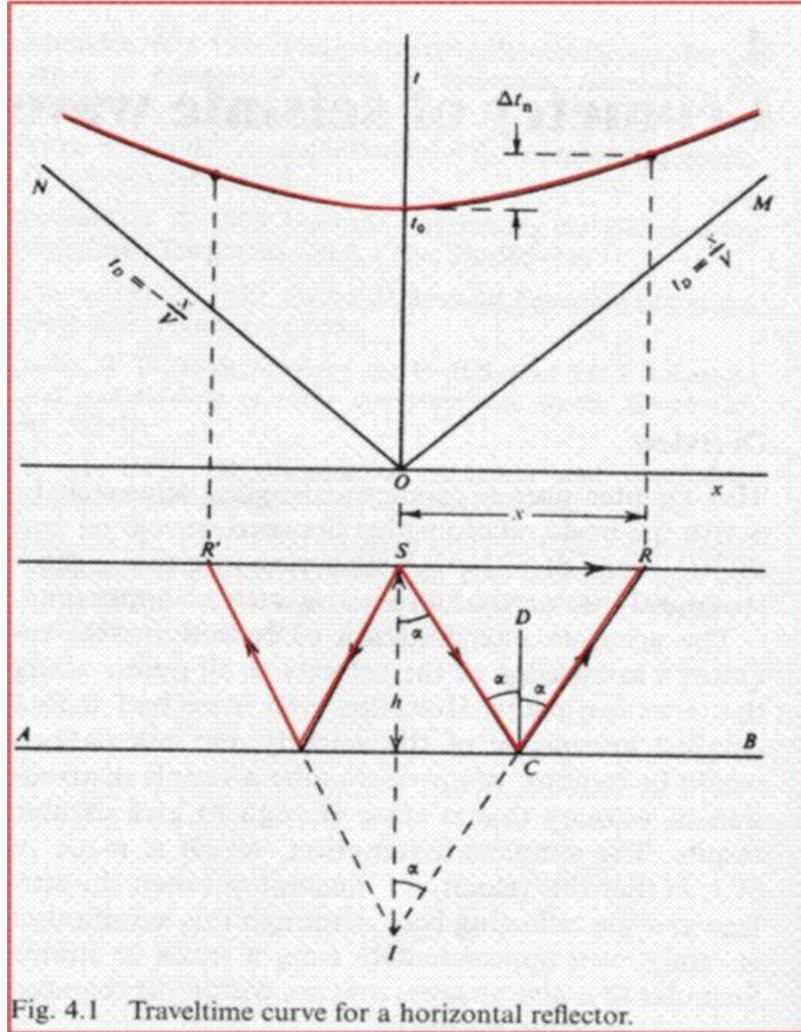
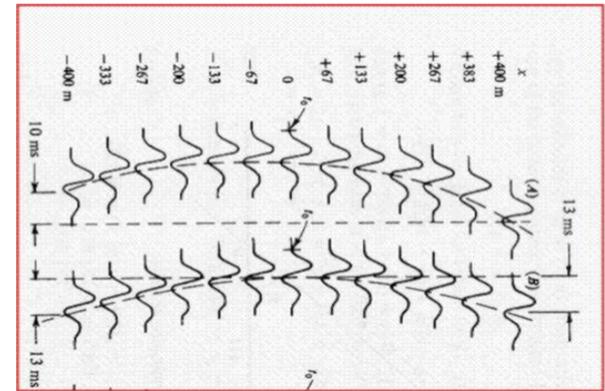


FIG. 4.1-13. Superposition of the zero-offset responses (b) of a continuum of Huygens' secondary sources as in (a).

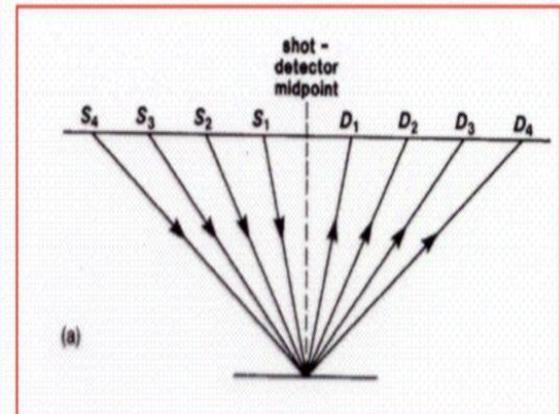
Onda riflessa

$$T^2 = \left(\frac{x}{v_1}\right)^2 + \left(\frac{2h}{v_1}\right)^2$$

L'equazione dell'onda riflessa viene descritta da una iperbole che tende asintoticamente alla retta dell'onda diretta.

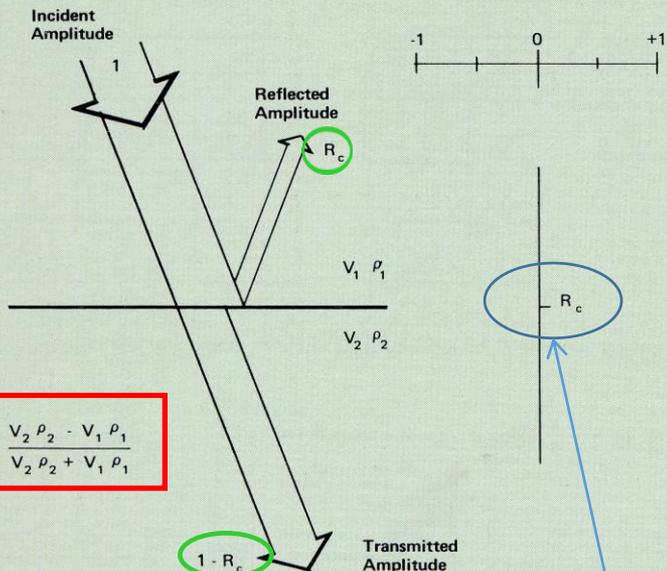


Common Shot Gather



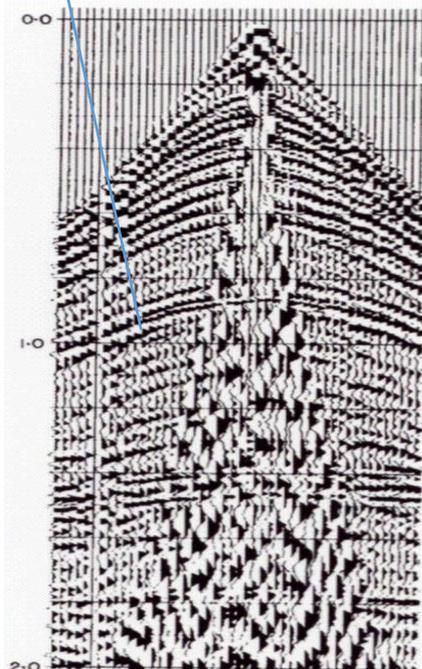
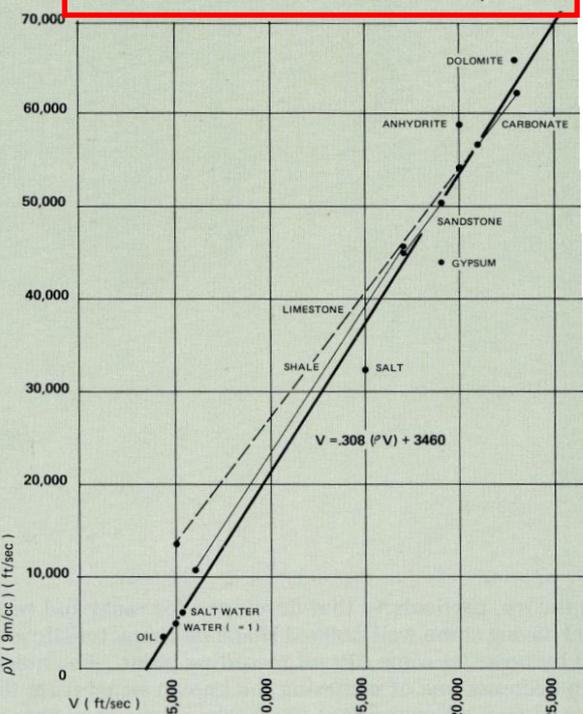
Common Midpoint Gather

## REFLECTION COEFFICIENT FORMULATION



$$R_c = \frac{V_2 \rho_2 - V_1 \rho_1}{V_2 \rho_2 + V_1 \rho_1}$$

## ACOUSTIC IMPEDENCE vs VELOCITY ( $\rho V$ vs $V$ )



Del Ben Anna - Interpretazione Sismica - Assunzioni Geofisiche di Base

## Impedenza Acustica $\rho v$ Coefficiente di Riflessione $R_c$

Le rocce sedimentarie sono le meno dense  $\sim 2.1 \pm 0.3 \text{ gr/cm}^3$   
Il contrasto di densità fra rocce sedimentarie adiacenti è raramente maggiore di  $0.25 \text{ g/cm}^3$

$$R_{c1} = \frac{V_2 - V_1}{V_2 + V_1} \quad \text{Basic approximation}$$

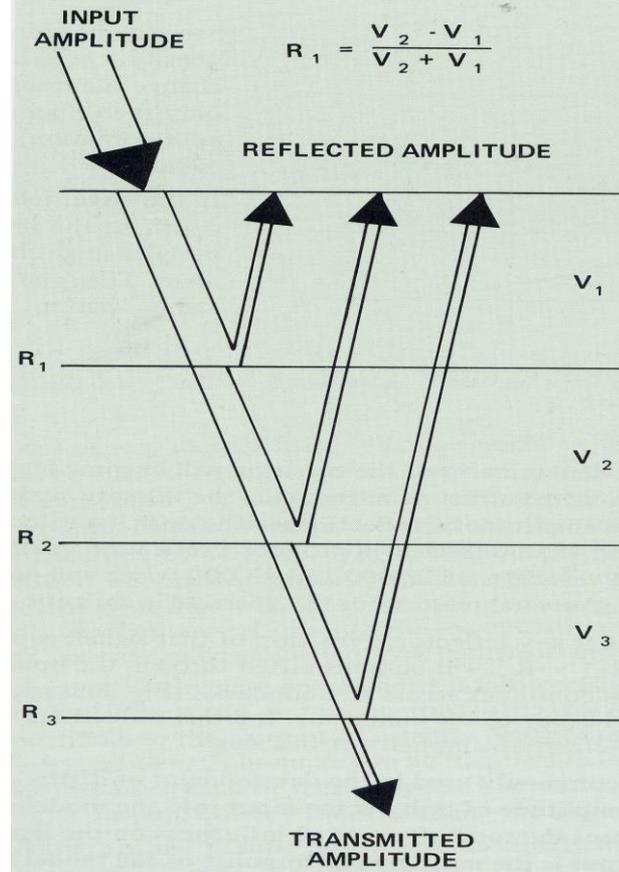
$$R_{c1} = \frac{\rho_2 V_2 - \rho_1 V_1}{\rho_2 V_2 + \rho_1 V_1} \quad \text{Better approximation}$$

$\rho = \text{Density}$

## SEISMIC REFLECTION MODEL

Formula semplificata

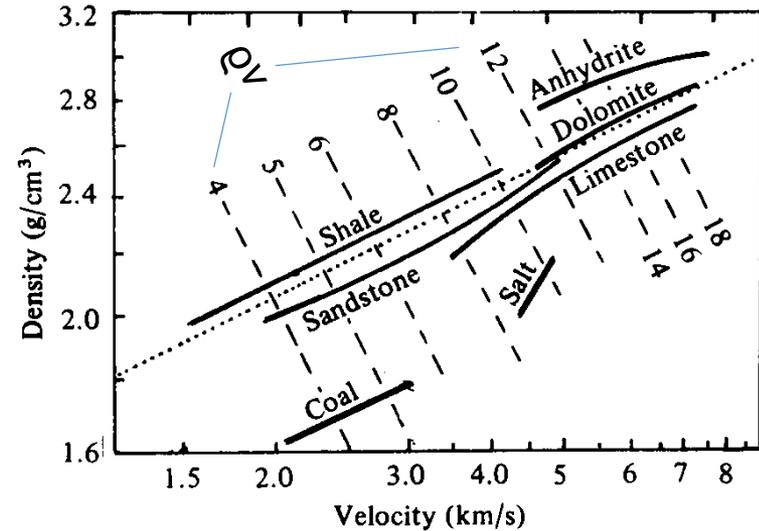
$$R_1 = \frac{V_2 - V_1}{V_2 + V_1}$$



## RELAZIONE tra DENSITA' e VELOCITA'

La funzione lineare tra impedenza acustica e velocità delle onde P (figura precedente) prevedrebbe una densità pressoché costante.

In effetti ciò non è vero: si ha generalmente una correlazione tra i valori di densità e velocità.



Una relazione più precisa è stata formulata da Gardner (nella formula  $velocità = \alpha$ )

Gardner's formula for density, this relationship given by  $\rho = c\alpha^{0.25}$ , where  $c$  is a constant that depends on the rock type, is useful to estimate density from velocity when the former is unknown. With the exception of anhydrites, most rock types — sandstones, shales, and carbonates, tend to obey Gardner's equation for density.

$c$  dipende dal tipo di roccia e dall'unità di misura di  $v$ :

-se  $V_p$  è espressa in m/sec  $\rightarrow c = 0.23$

-se  $V_p$  è espressa in piedi/sec  $\rightarrow c = 0.31$

# Alcuni esempi di valori di

velocità  $v_p$     densità  $\rho$     coefficienti di riflessione  $R_c$   
 per situazioni litologiche standard

Table 3.1 *Energy reflected at interface between two media*

Interface	First medium		Second medium		$Z_1/Z_2$	$R$	$E_R$
	Velocity	Density	Velocity	Density			
Sandstone on limestone	2.0	2.4	3.0	2.4	0.67	0.2	0.040
Limestone on sandstone	3.0	2.4	2.0	2.4	1.5	-0.2	0.040
Shallow interface	2.1	2.4	2.3	2.4	0.93	0.045	0.0021
Deep interface	4.3	2.4	4.5	2.4	0.97	0.022	0.0005
"Soft" ocean bottom	1.5	1.0	1.5	2.0	0.50	0.33	0.11
"Hard" ocean bottom	1.5	1.0	3.0	2.5	0.20	0.67	0.44
Surface of ocean (from below)	1.5	1.0	0.36	0.0012	3800	-0.9994	0.9988
Base of weathering	0.5	1.5	2.0	2.0	0.19	0.68	0.47
Shale over water sand	2.4	2.3	2.5	2.3	0.96	0.02	0.0004
Shale over gas sand	2.4	2.3	2.2	1.8	1.39	-0.16	0.027
Gas sand over water sand	2.2	1.8	2.5	2.3	0.69	0.18	0.034

All velocities in km/s, densities in g/cm<sup>3</sup>; the minus signs indicate 180° phase reversal.

Type of formation	P wave velocity (m/s)	S wave velocity (m/s)	Density (g/cm <sup>3</sup> )	Density of constituent crystal (g/cm <sup>3</sup> )
Scree, vegetal soil	300-700	100-300	1.7-2.4	-
Dry sands	400-1200	100-500	1.5-1.7	2.65 quartz
Wet sands	1500-2000	400-600	1.9-2.1	2.65 quartz
Saturated shales and clays	1100-2500	200-800	2.0-2.4	-
Marls	2000-3000	750-1500	2.1-2.6	-
Saturated shale and sand sections	1500-2200	500-750	2.1-2.4	-
Porous and saturated sandstones	2000-3500	800-1800	2.1-2.4	2.65 quartz
Limestones	3500-6000	2000-3300	2.4-2.7	2.71 calcite
Chalk	2300-2600	1100-1300	1.8-3.1	2.71 calcite
Salt	4500-5500	2500-3100	2.1-2.3	2.1 halite
Anhydrite	4000-5500	2200-3100	2.9-3.0	-
Dolomite	3500-6500	1900-3600	2.5-2.9	(Ca, Mg) CO <sub>3</sub> 2.8-2.9
Granite	4500-6000	2500-3300	2.5-2.7	-
Basalt	5000-6000	2800-3400	2.7-3.1	-
Gneiss	4400-5200	2700-3200	2.5-2.7	-
Coal	2200-2700	1000-1400	1.3-1.8	-
Water	1450-1500	-	1.0	-
Ice	3400-3800	1700-1900	0.9	-
Oil	1200-1250	-	0.6-0.9	-

Typical rock velocities, from Bourbie, Coussy, and Zinszner, Acoustics of Porous Media, Gulf Publishing

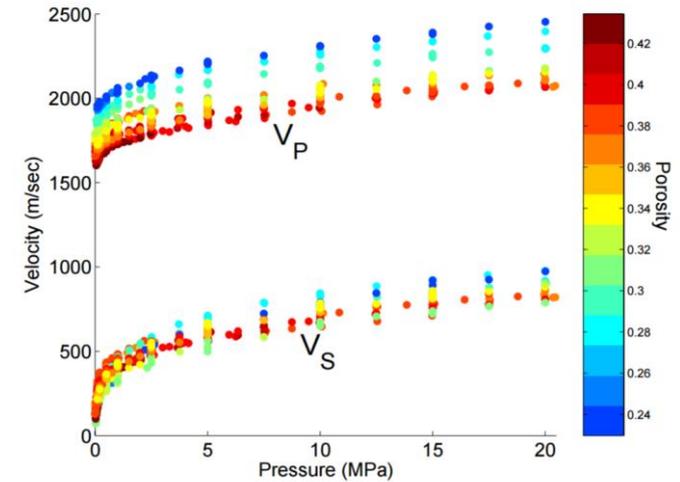


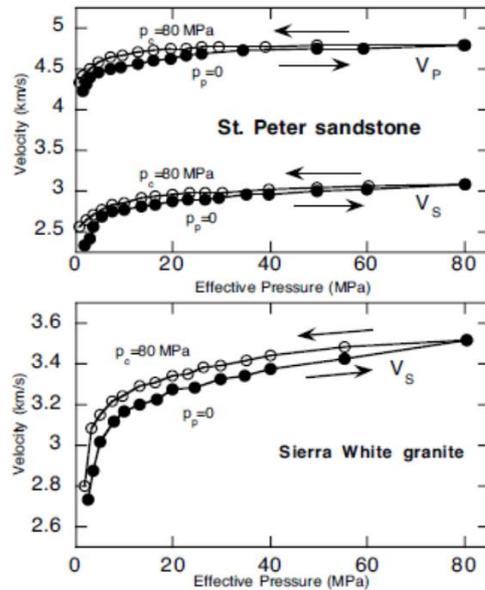
Figure 4.4: Gassmann fluid-substituted velocity data plotted against pressure, color-coded by porosity. The systematic porosity dependence of the compressional-wave velocities is easily visible.

Zimmer, 2004

La velocità  $V_P$  di una roccia dipende da:

- tipo di roccia: importante, in particolare, soprattutto per pressioni basse (ridotta profondità), il contenuto in sedimenti fini/argille
- porosità (variabile con profondità)
- saturazione in fluidi
- pressione litostatica
- pressione nei pori (agisce } **pressione effettiva**)  
più spesso in senso opposto alla pressione litostatica)
- presenza di microfessure (...both -P & S- seismic wave velocities decrease with increasing crack density. By O'Connell and Budiansky, 1974)

## Parameters That Influence Seismic Velocity

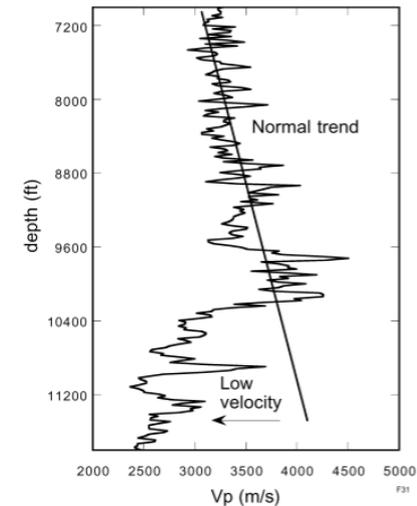


Experiments that illustrate the effective pressure law. In the first part of the experiment, effective pressure is increased by increasing confining pressure from 0 to 80 MPa, while keeping pore pressure zero (solid dots). Then, effective pressure is decreased by keeping confining pressure fixed at 80 MPa, but pumping up the pore pressure from 0 to nearly 80 MPa (open circles). (Jones, 1983.)

The curves trace approximately (but not exactly) the same trend. There is some hysteresis, probably associated with frictional adjustment of crack faces and grain boundaries. For most purposes, the hysteresis is small compared to more serious difficulties measuring velocities, so we assume that the effective pressure law can be applied. This is a tremendous convenience, since most laboratory measurements are made with pore pressure equal 0.

## Parameters That Influence Seismic Velocity

### Seismic Velocity and Overpressure

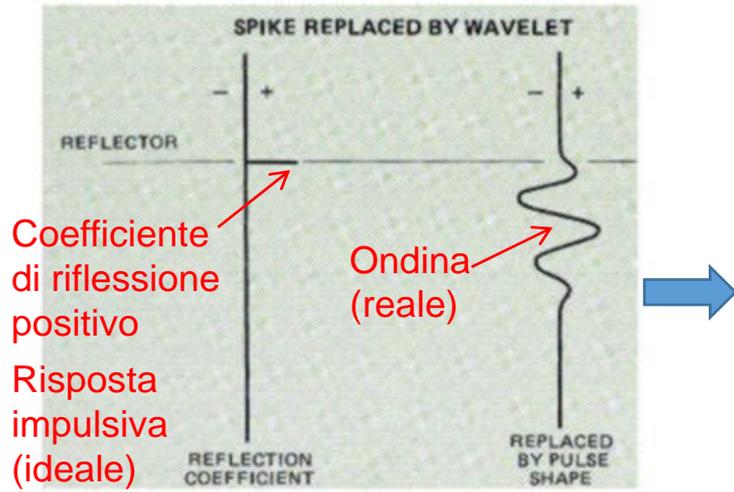


A typical approach to overpressure analysis is to look for low velocity deviations from normal depth trends. Caution: when overpressure is "late stage," estimates of pressure can be too low.

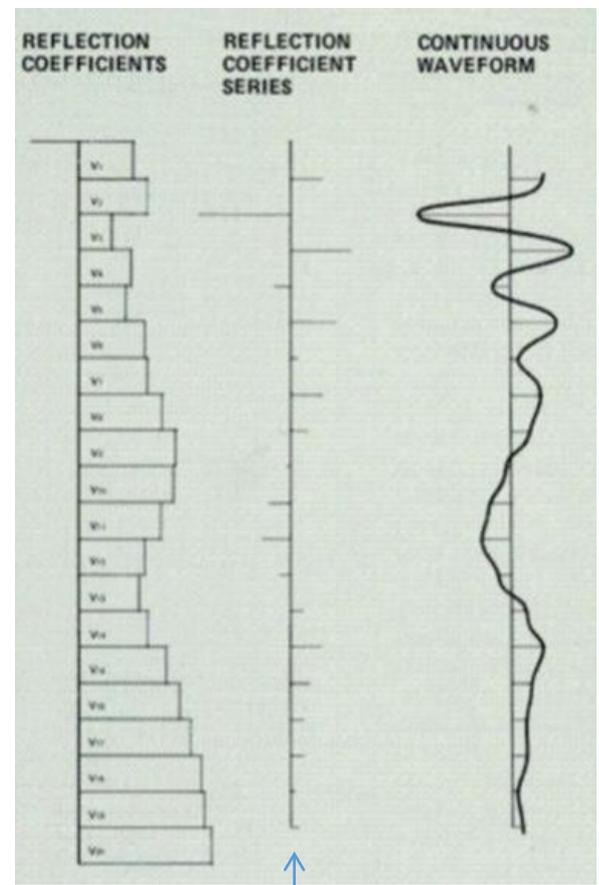
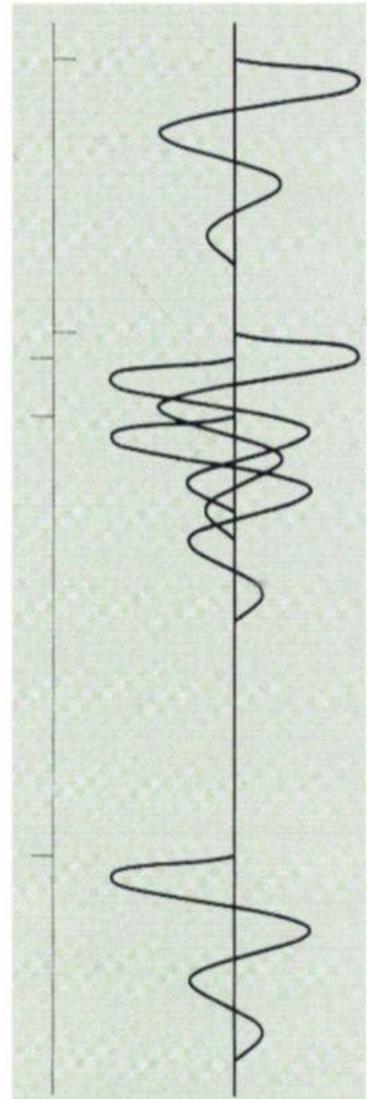
Alte pressioni nei pori protratte nel tempo possono inibire i processi diagenetici e preservare la porosità: la tendenza sarà quella di mantenere velocità  $V_p$  più basse

# Cos'è un Sismogramma?

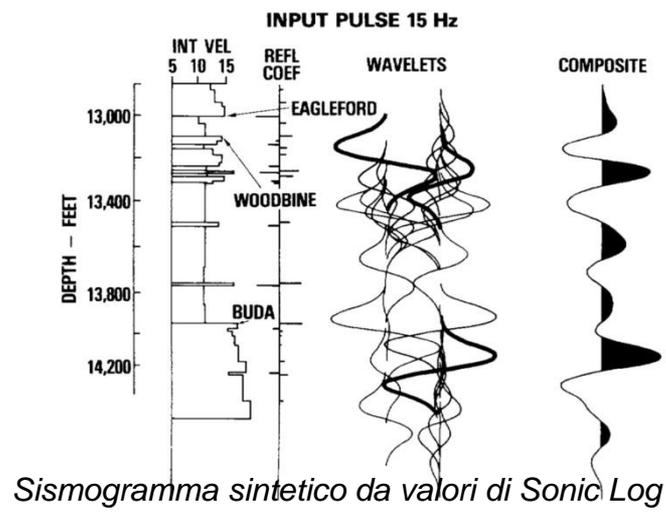
Il modello più semplice di riflessione considera due strati omogenei sovrapposti caratterizzati da diverse proprietà elastiche (->  $V_p$  e  $\rho$ )



Coefficiente di riflessione positivo  
Risposta impulsiva (ideale)



Si noti la diminuzione dei coefficienti di riflessione con la profondità .....



Sismogramma sintetico da valori di Sonic Log

FIG. 14—Synthetic seismogram, Shell 1 Southland Paper Mills, Polk County, Texas. Interval velocity in thousands of feet per second.