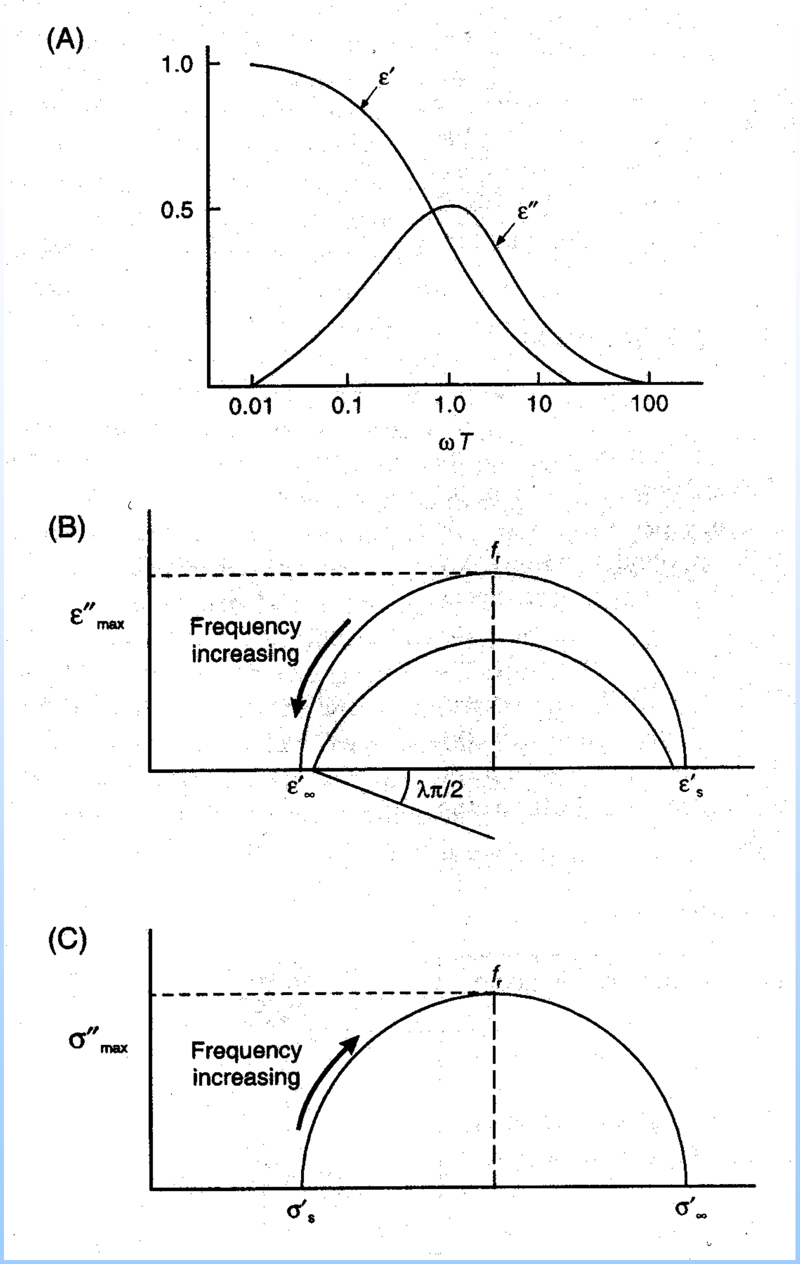
GPR:
sintesi di permettivita’ e conduttivita’ complesse

$\varepsilon = \varepsilon' + j\varepsilon''$ se mezzo non conduttivo

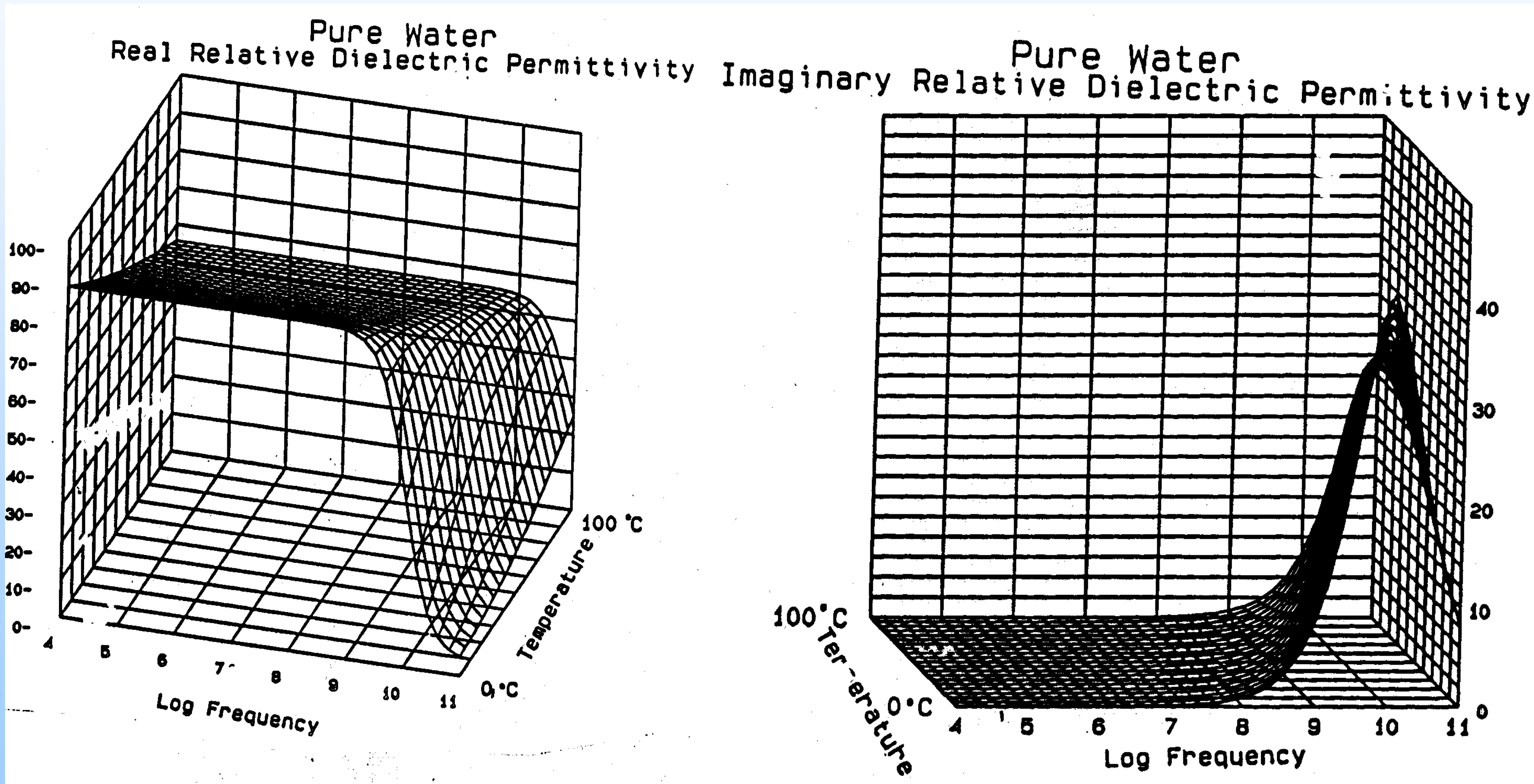
$$\varepsilon = \varepsilon' + j\left(\varepsilon'' + \frac{\sigma_s}{\omega\varepsilon_o}\right)$$ se mezzo conduttivo

$\sigma = \sigma' + j\sigma'' = j\omega\varepsilon_o\varepsilon$ Relazione conduttivita’-permettivita’ complesse

GPR:
diagramma di Cole-Cole
per permettivita’ complessa



GPR:
parte reale ed immaginaria permettivita' acqua



GPR:
velocita’ onde EM per diversi materiali

Material	ε_r	V(mm/ns)
Air	1	300
Water (fresh)	81	33
Water (sea)	81	33
Polar snow	1.4–3	194–252
Polar ice	3–3.15	168
Temperate ice	3.2	167
Pure ice	3.2	167
Freshwater lake ice	4	150
Sea ice	2.5–8	78–157
Permafrost	1–8	106–300
Coastal sand (dry)	10	95
Sand (dry)	3–6	120–170
Sand (wet)	25–30	55–60
Silt (wet)	10	95
Clay (wet)	8–15	86–110
Clay soil (dry)	3	173
Marsh	12	86
Agricultural land	15	77
Pastoral land	13	83
Average ‘soil’	16	75
Granite	5–8	106–120
Limestone	7–9	100–113
Dolomite	6.8–8	106–115
Basalt (wet)	8	106
Shale (wet)	7	113
Sandstone (wet)	6	112
Coal	4–5	134–150
Quartz	4.3	145
Concrete	6–30	55–112
Asphalt	3–5	134–173
PVC, Epoxy, Polyesters	3	173

GPR:
permettivita’ dielettrica e porosita’

$$\varepsilon_r = (1-\phi)\varepsilon_m + \phi\varepsilon_w$$

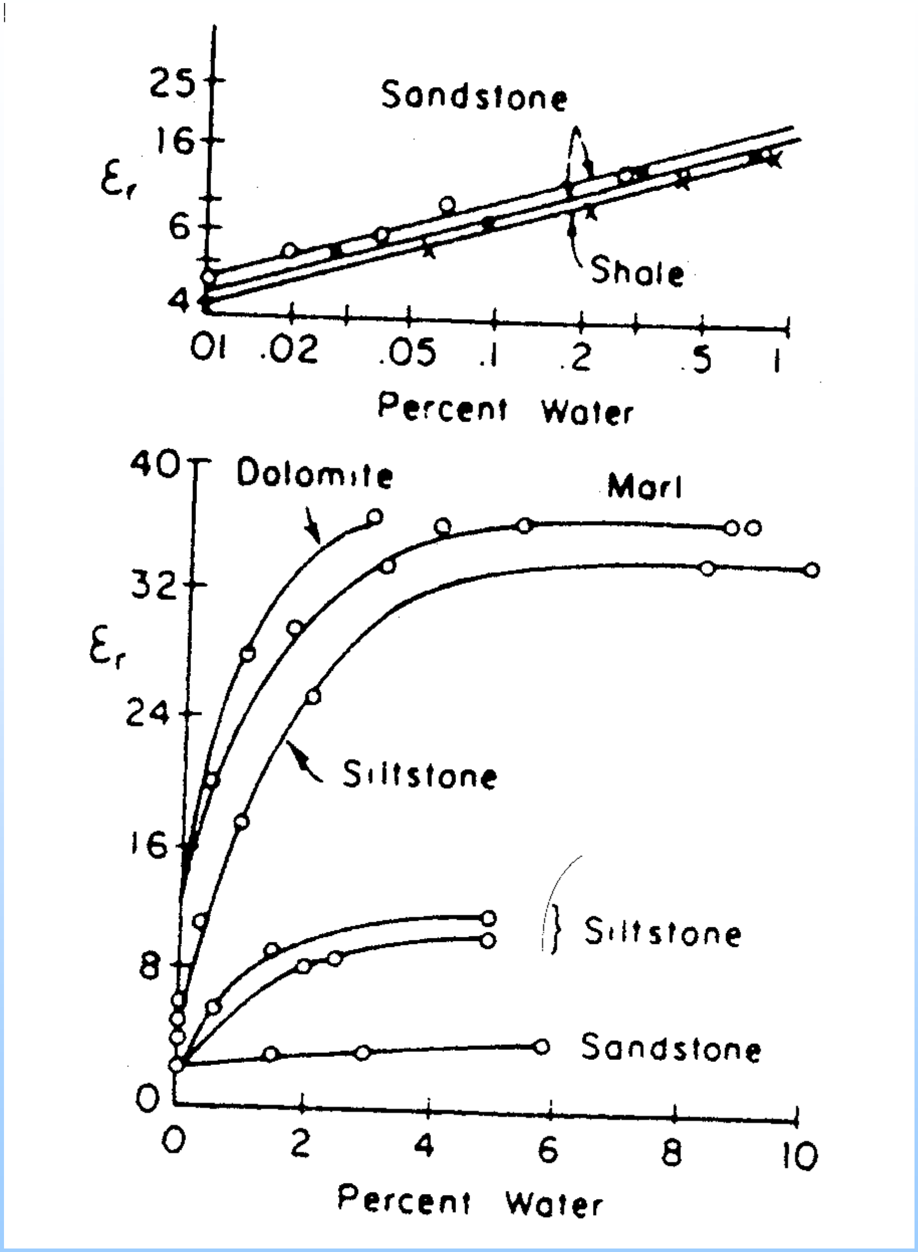
Se campo elettrico parallelo alla stratificazione

$$\varepsilon_r = \frac{\varepsilon_m \varepsilon_w}{(1-\phi)\varepsilon_m + \phi\varepsilon_w}$$

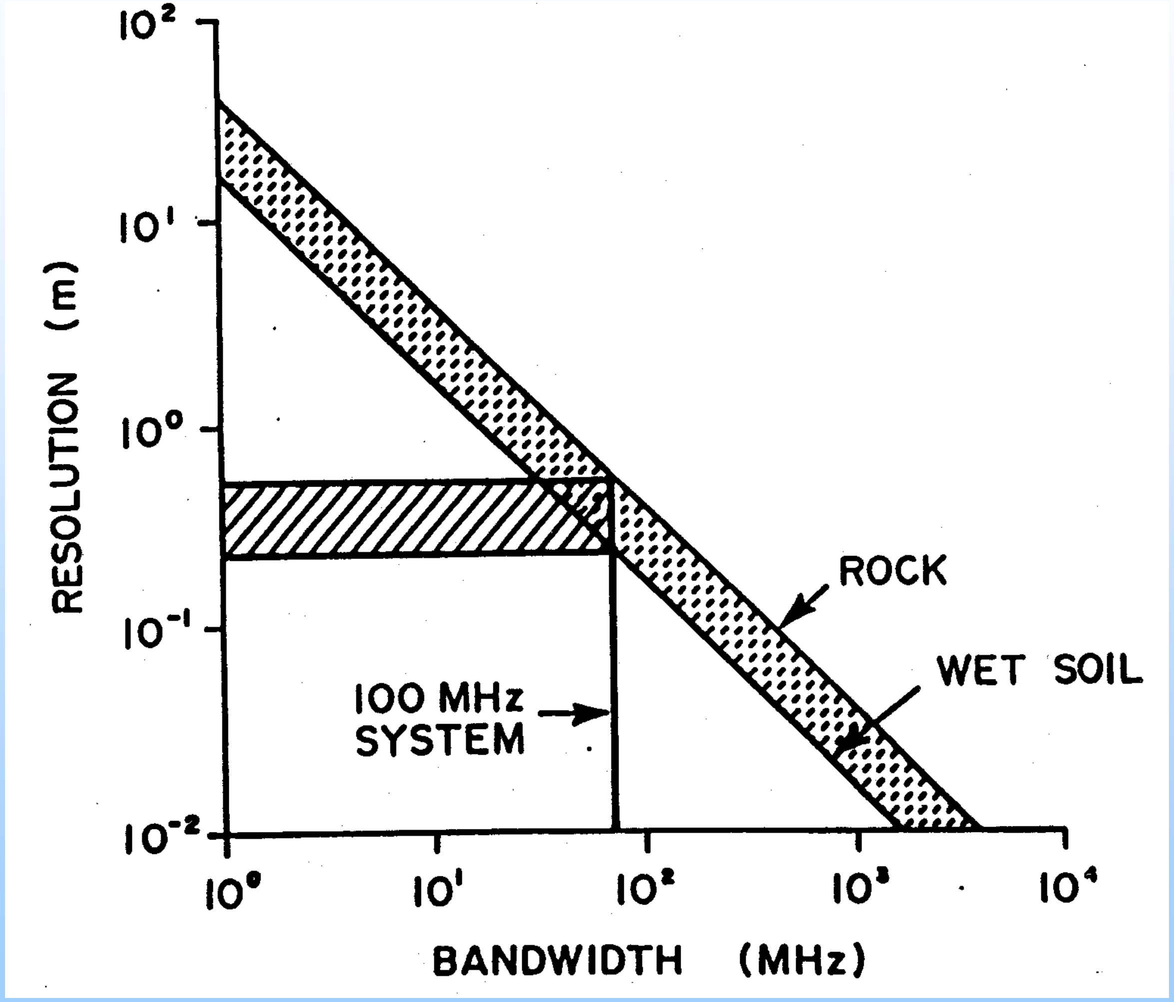
Se campo elettrico normale alla stratificazione

$$v = \frac{c}{\left[(1-\phi)\varepsilon_m + \phi\varepsilon_w\right]^{\frac{1}{2}}}$$

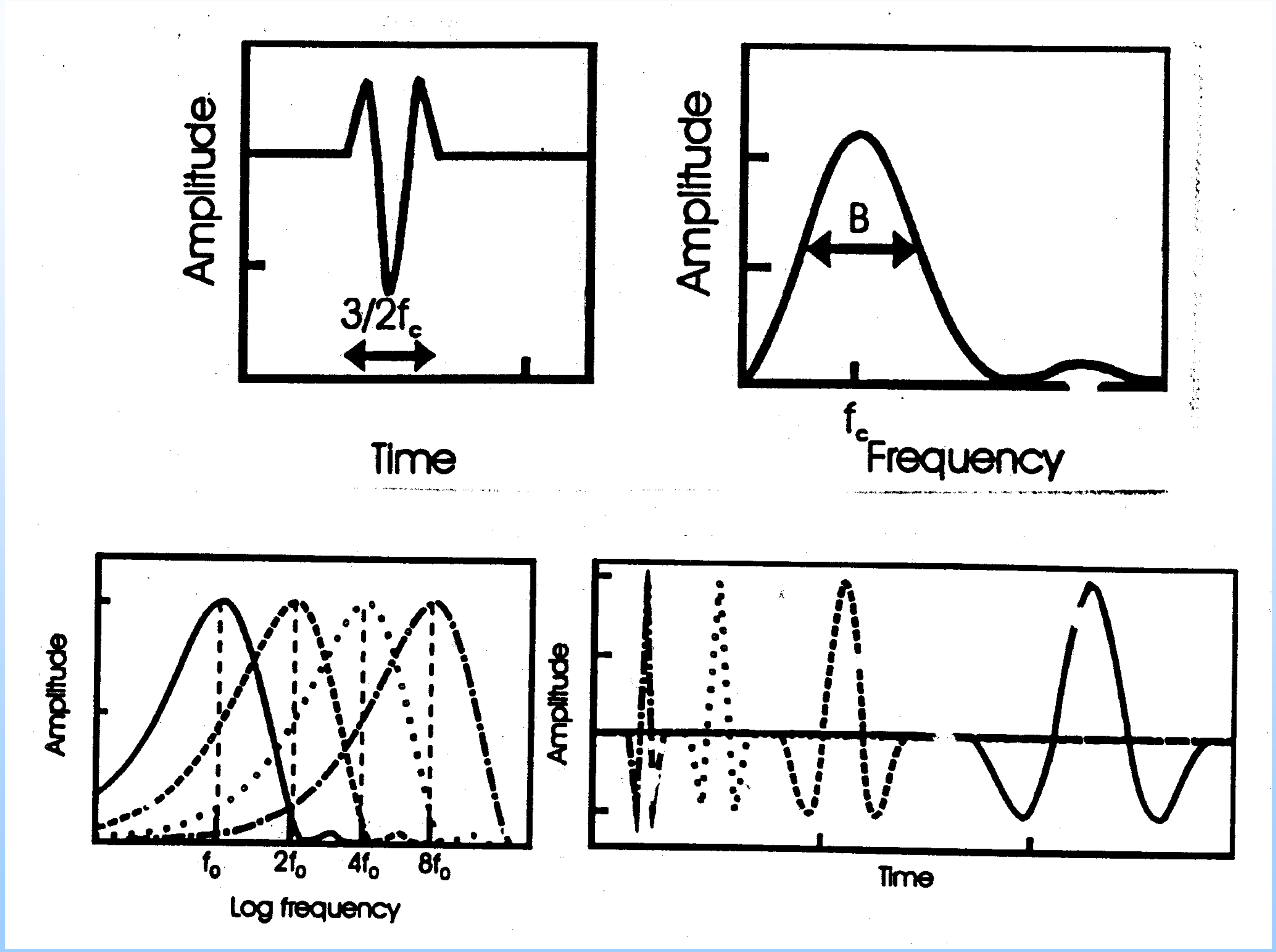
GPR:
permettivita' dielettrica e contenuto in acqua



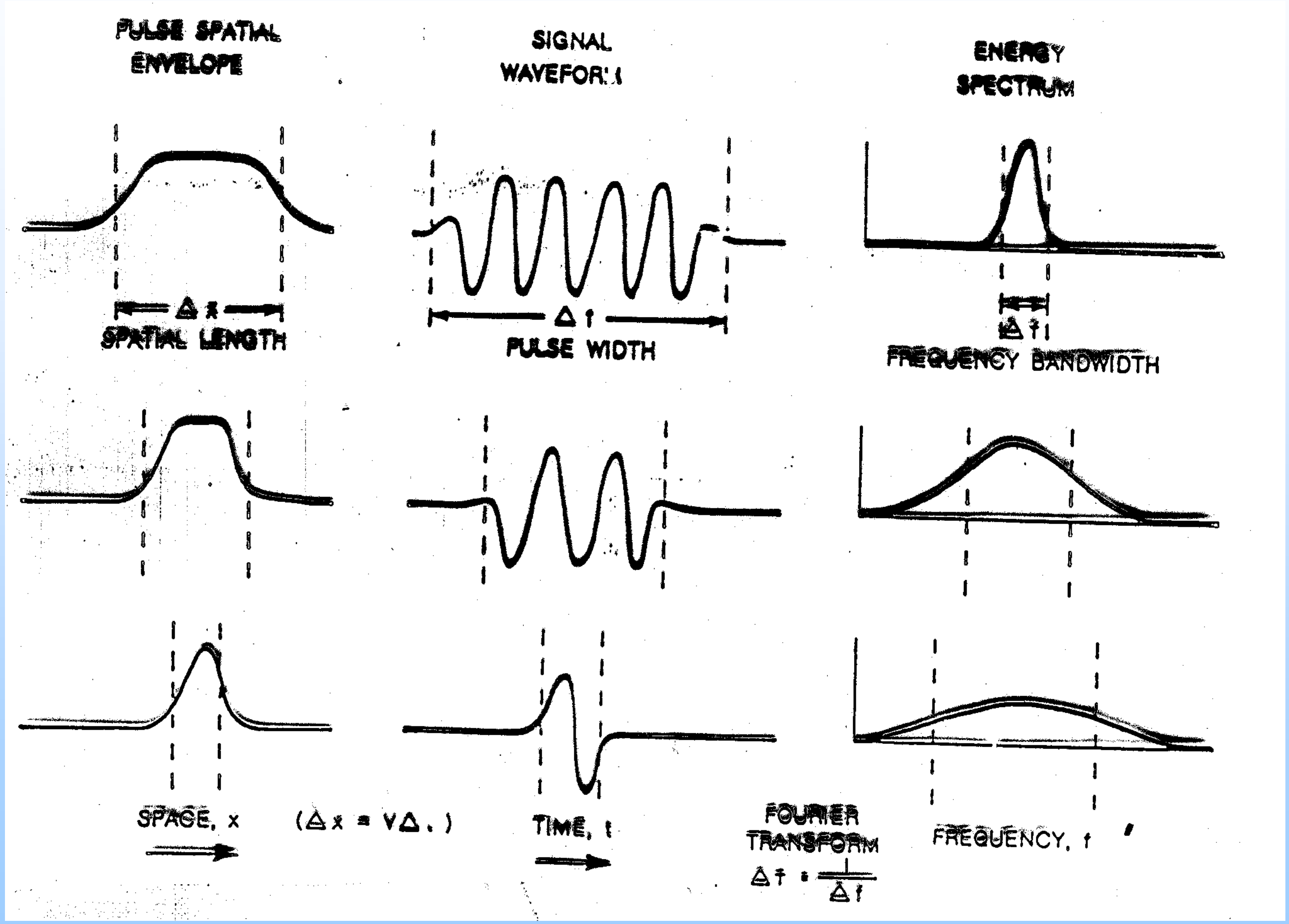
GPR:
velocita’ e risoluzione verticale



GPR:
ampiezza di banda e durata impulso



GPR:
ampiezza di banda e durata impulso (2)



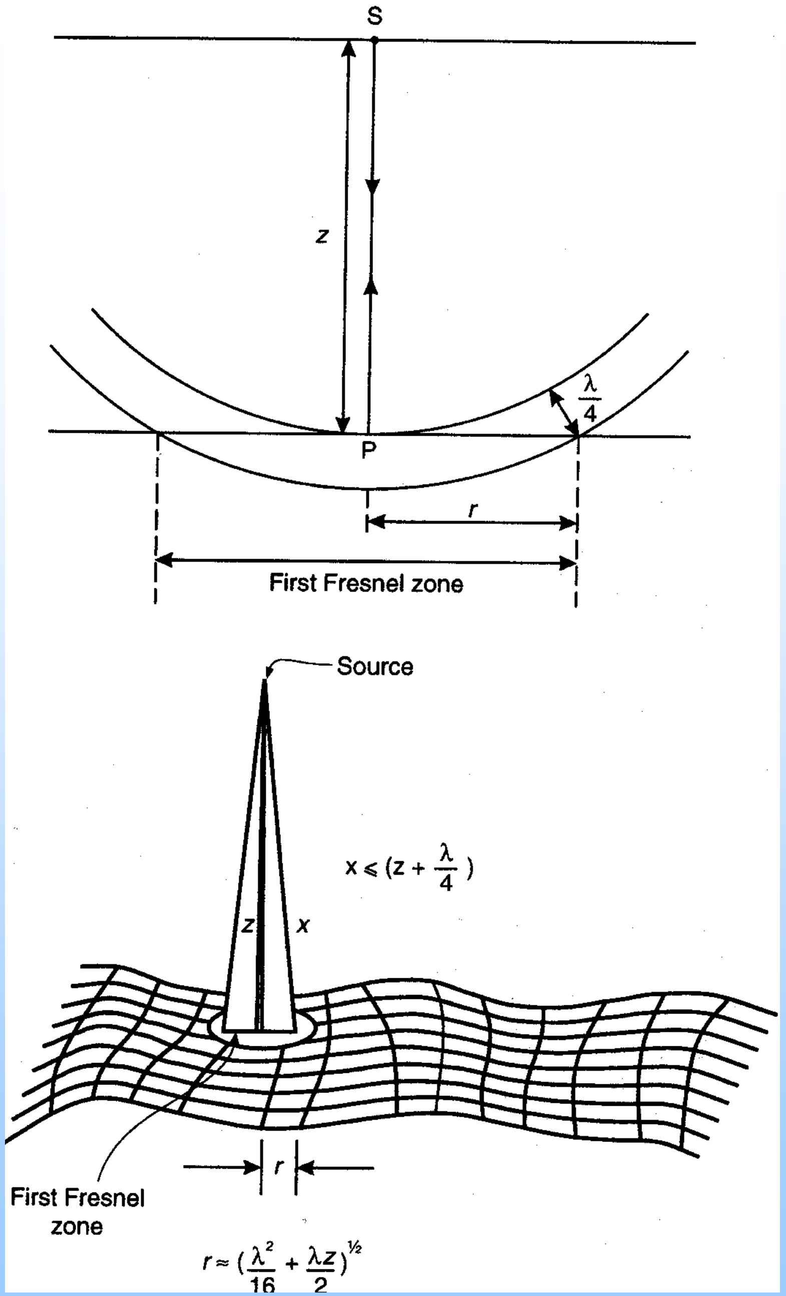
GPR:
risoluzione verticale

R_v : teoricamente uguale a $\lambda/4$ (nella pratica spesso non superiore a $\lambda/3$)

	Antenna frequency (MHz)		
	120	500	900
Suolo			
λ (cm)	62.5	15	8
R_v (cm)	15.6	3.75	2
Roccia			
λ (cm)	92	22	12
R_v (cm)	23	5.5	3

GPR:
risoluzione orizzontale

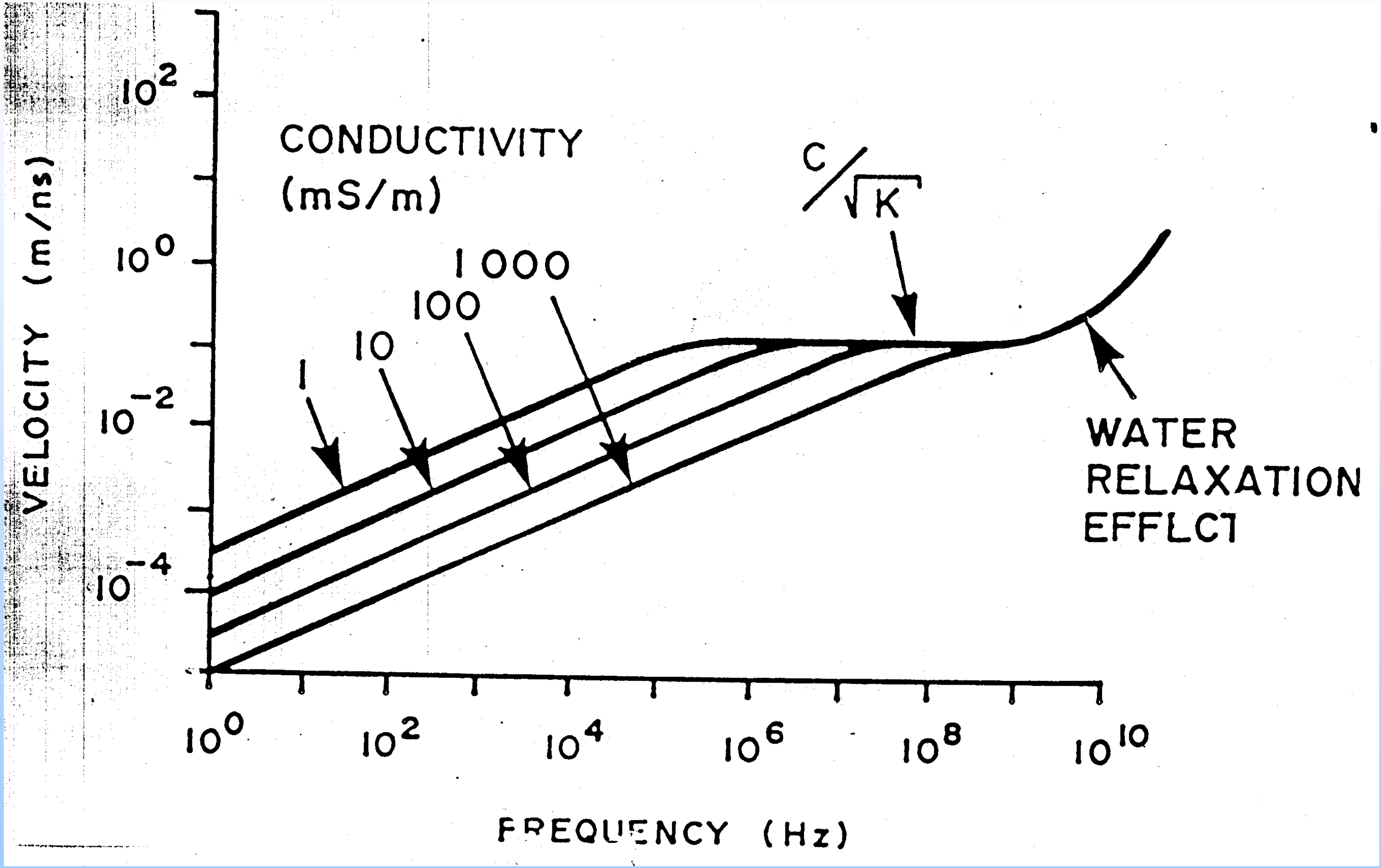
R_h : inversamente proporzionale a $(\alpha)^{1/2}$, e' massima su mezzi ad alta perdita. Dipende da dimensioni prima zona Fresnel



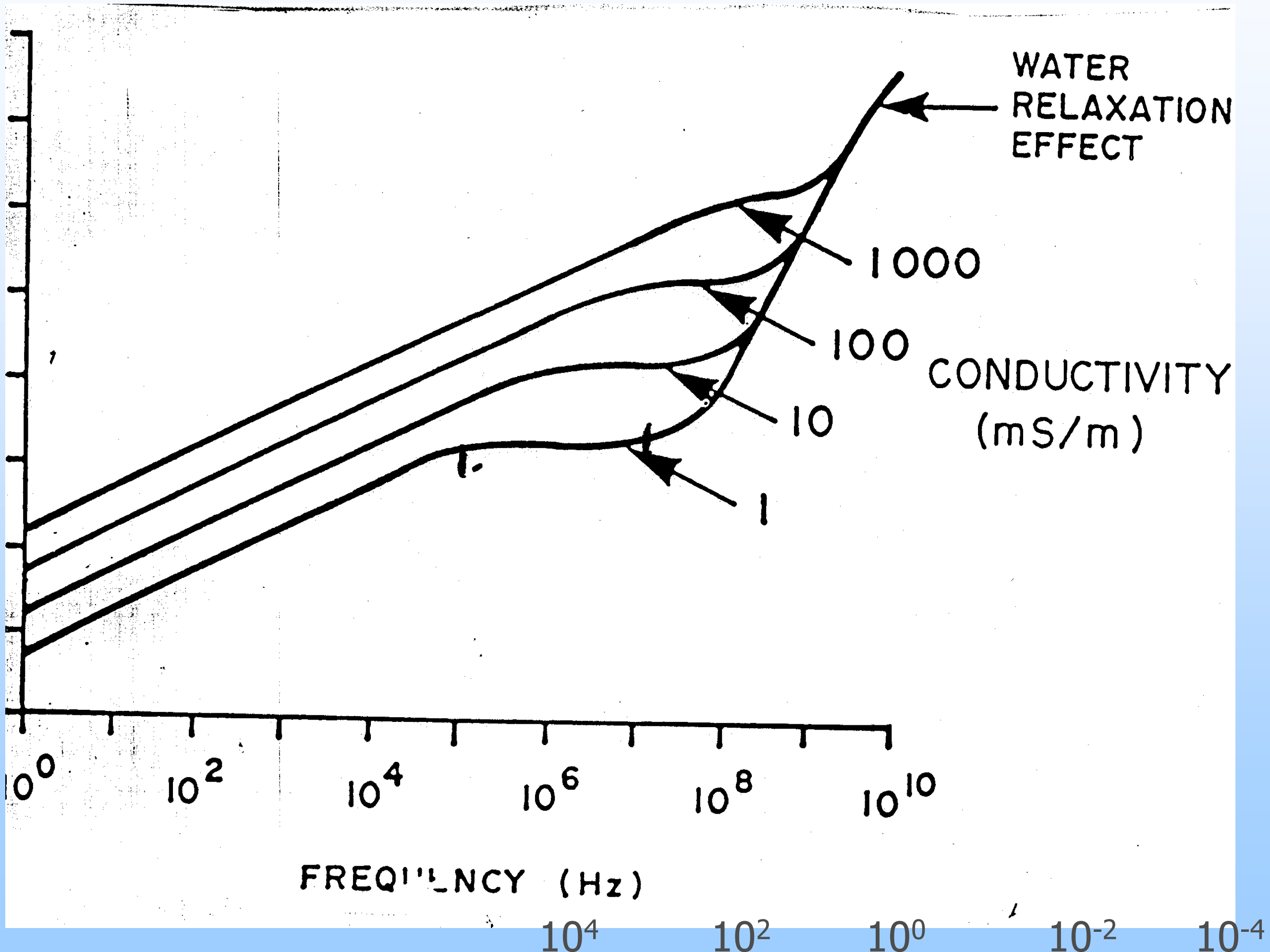
GPR:
proprieta' materiali di interesse per la risoluzione

Material	K	σ (mS/m)	V (m/ns)	α (dB/m)
Air	1	0	0.30	0
Distilled water	80	0.01	0.033	2×10^{-3}
Fresh water	80	0.5	0.033	0.1
Sea water	80	3×10^{4}	0.01	10^{3}
Dry sand	3–5	0.01	0.15	0.01
Saturated sand	20–30	0.1–1.0	0.06	0.03–0.3
Limestone	4–8	0.5–2	0.12	0.4–1
Shales	5–15	1–100	0.09	1–100
Silts	5–30	1–100	0.07	1–100
Clays	5–40	2–1000	0.06	1–300
Granite	4–6	0.01–1	0.13	0.01–1
Dry salt	5–6	0.01–1	0.13	0.01–1
Ice	3–4	0.01	0.16	0.01

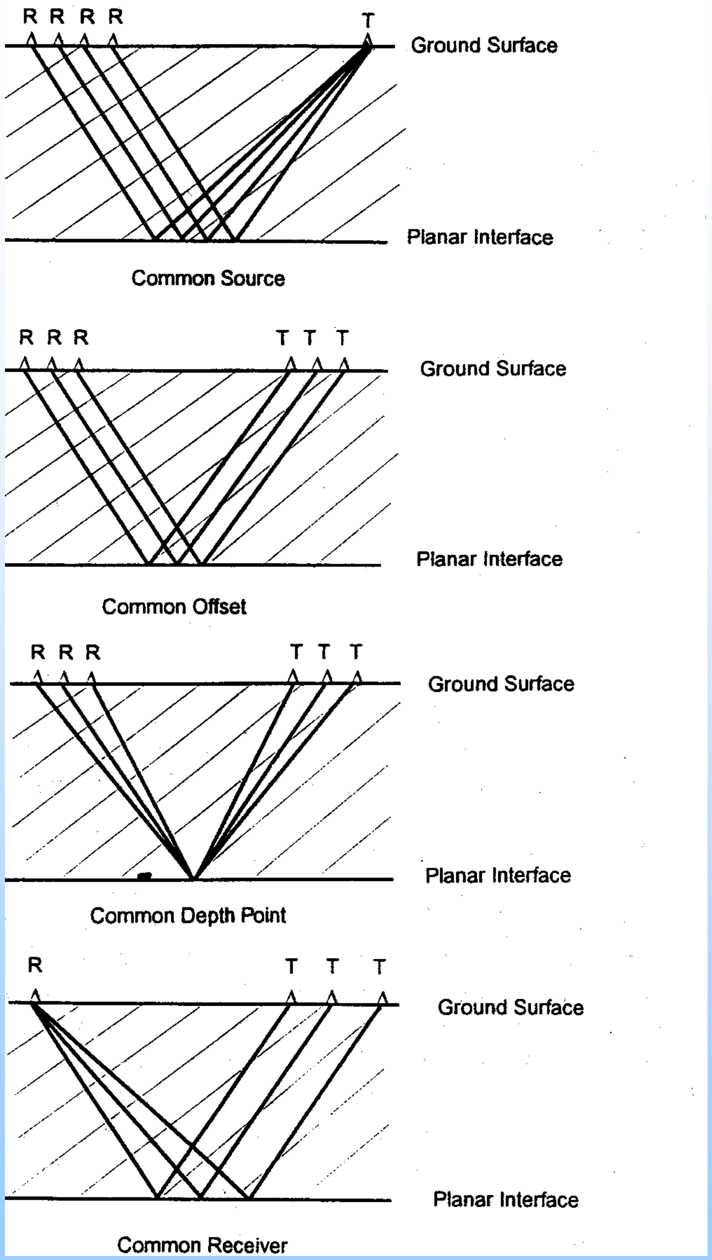
GPR:
intervallo di frequenza utile



GPR:
intervallo di frequenza utile (2)



GPR:
modalita' di acquisizione dati



REFLECTIONS

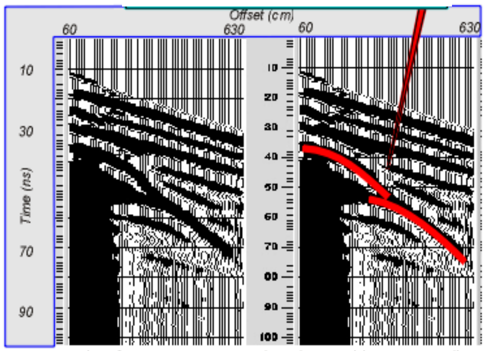


Fig.5a - Example of 200 MHz CMP gather (original/interpreted): DC removed by standard algorithms

REFLECTIONS

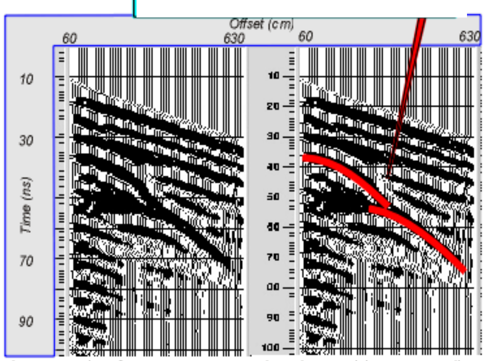


Fig.5b - Example of 200 MHz CMP gather (original/interpreted): DC removed by proprietary algorithms

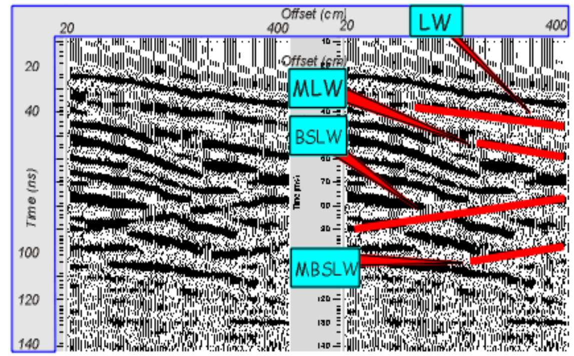


Fig.5c - Example of 200 MHz SHOT gather [LW=lateral wave, MLW=multiple LW, BSLW= backscattered LW, MBSLW= multiple BSLW]

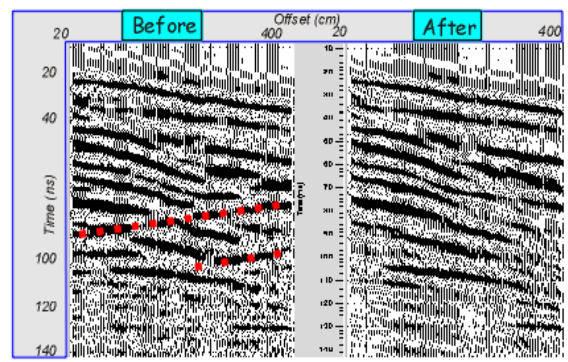
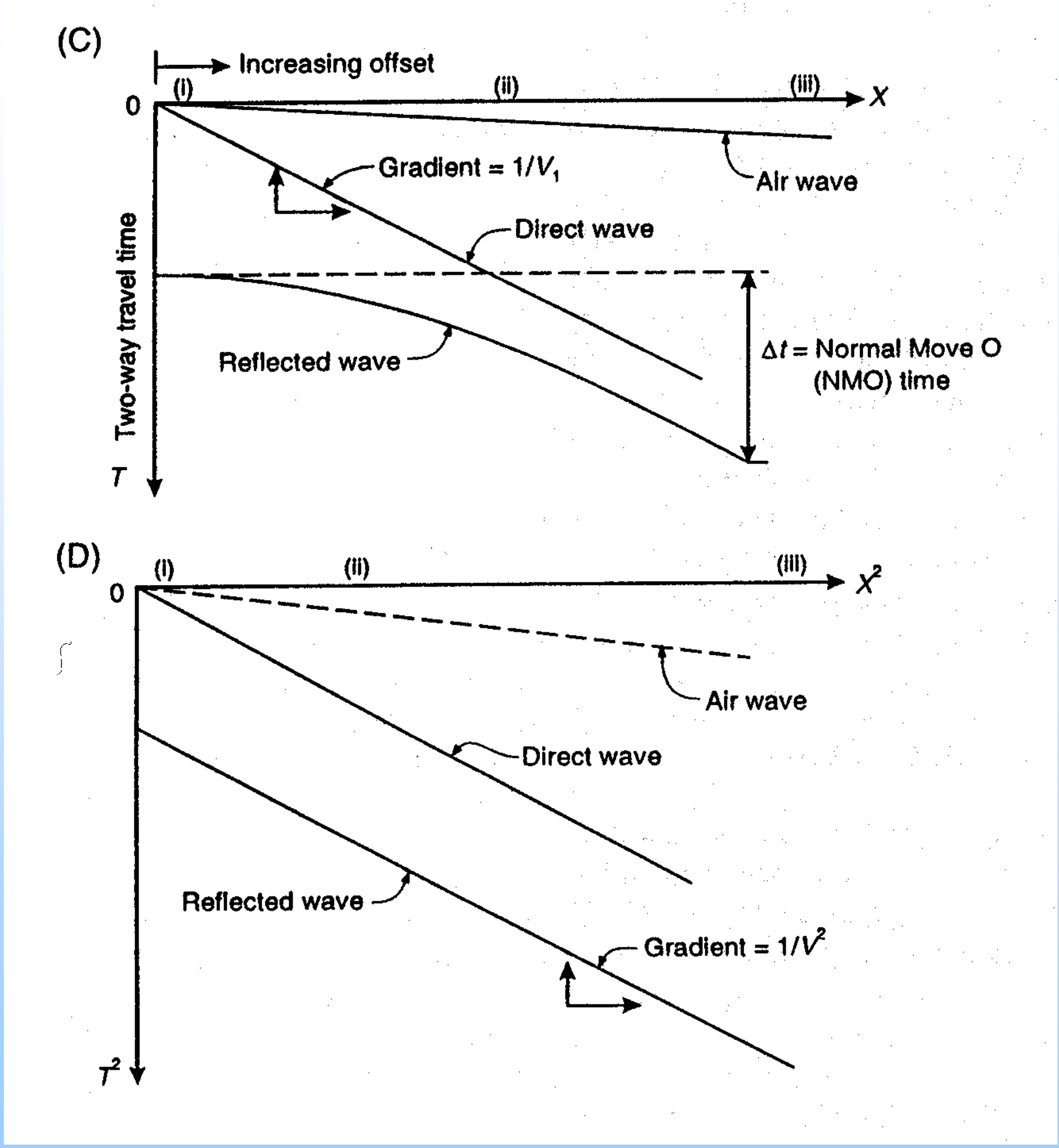


Fig.5d - Example of 200 MHz SHOT gather before/after BSLW and MBSLW removal removal by means of proprietary algorithms

GPR:
principali eventi onde dirette

$$t_D = \frac{x}{v}$$

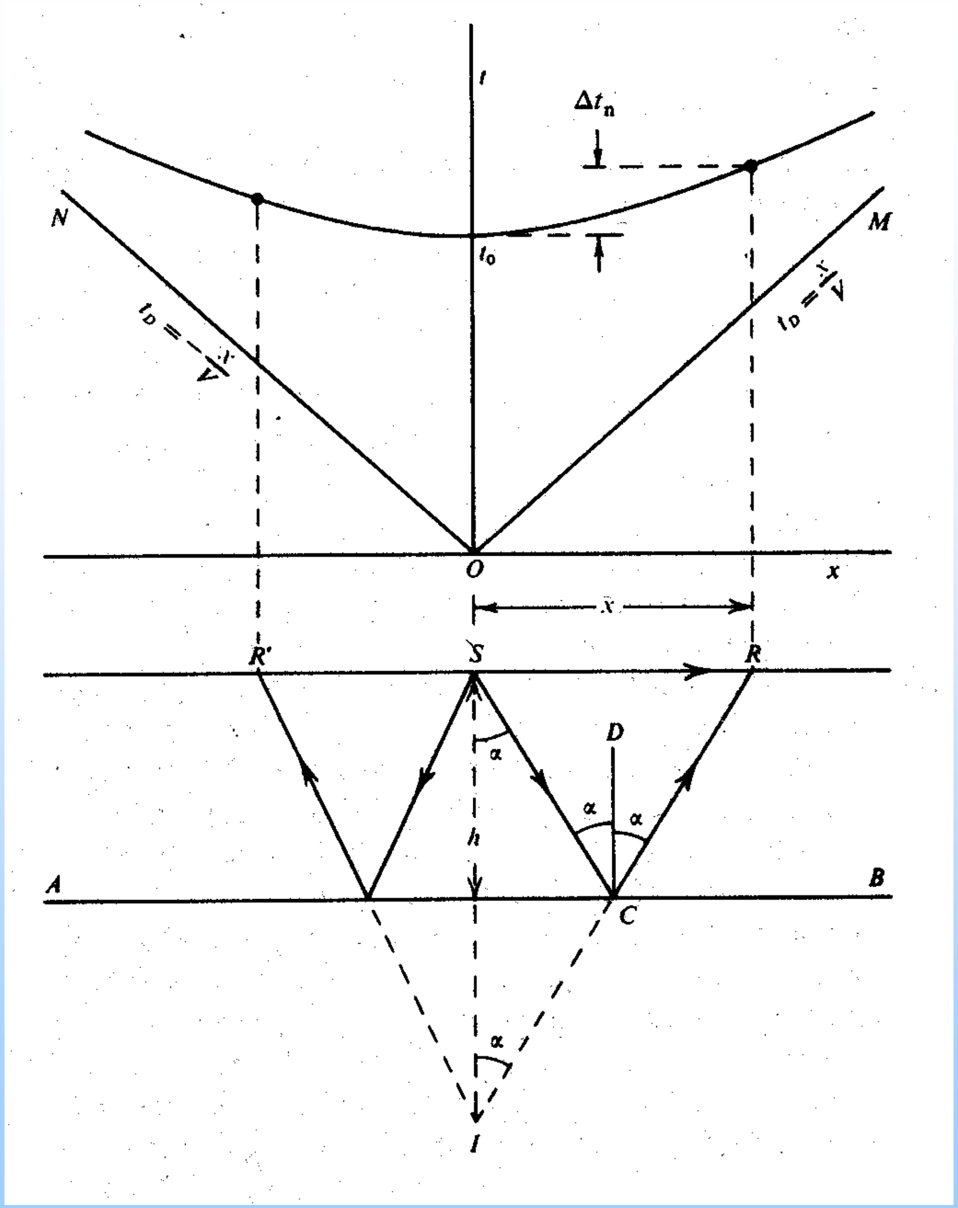


GPR:
principali eventi onde riflesse

$$v^2t^2 = x^2 + 4h^2$$

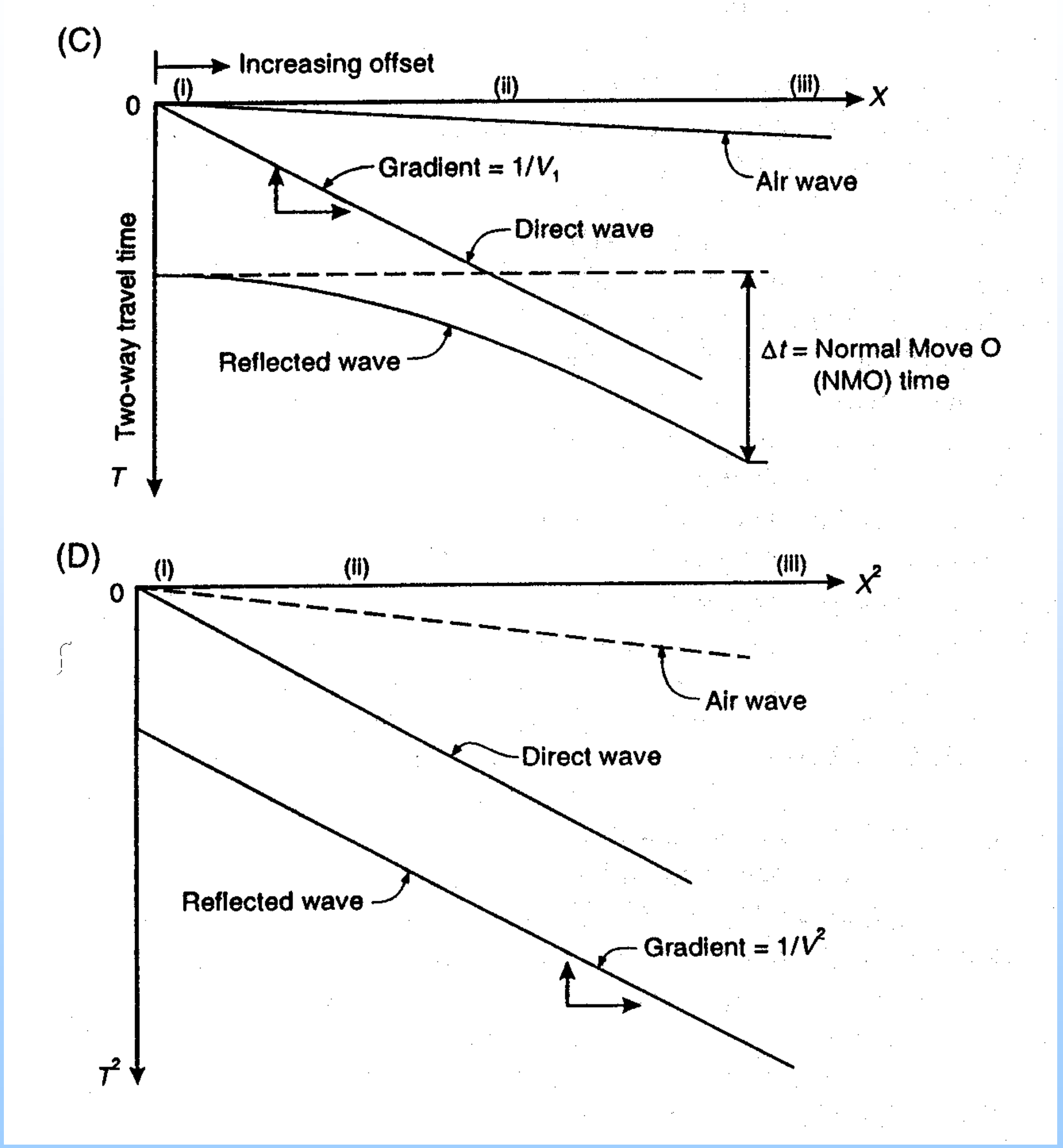
$$\frac{v^2t^2}{4h^2} - \frac{x^2}{4h^2} = 1$$

$$h = \frac{vt_o}{2}$$



GPR:
principali eventi onde riflesse

$$t^2 = \frac{x^2}{v^2} + \frac{4h^2}{v^2} = \frac{x^2}{v^2} + t_o^2$$



GPR:
Normal Move Out

$$t = \frac{2h}{v}\left[1+\left(\frac{x}{2h}\right)^2\right]^{\frac{1}{2}} = t_o\left[1+\left(\frac{x}{vt_o}\right)^2\right]^{\frac{1}{2}} =$$

$$= t_o\left[1+\frac{1}{2}\left(\frac{x}{vt_o}\right)^2 - \frac{1}{8}\left(\frac{x}{vt_o}\right)^4 + \ldots\right]$$

$$\Delta t_{nmo} \approx \frac{x^2}{2v^2 t_o}$$

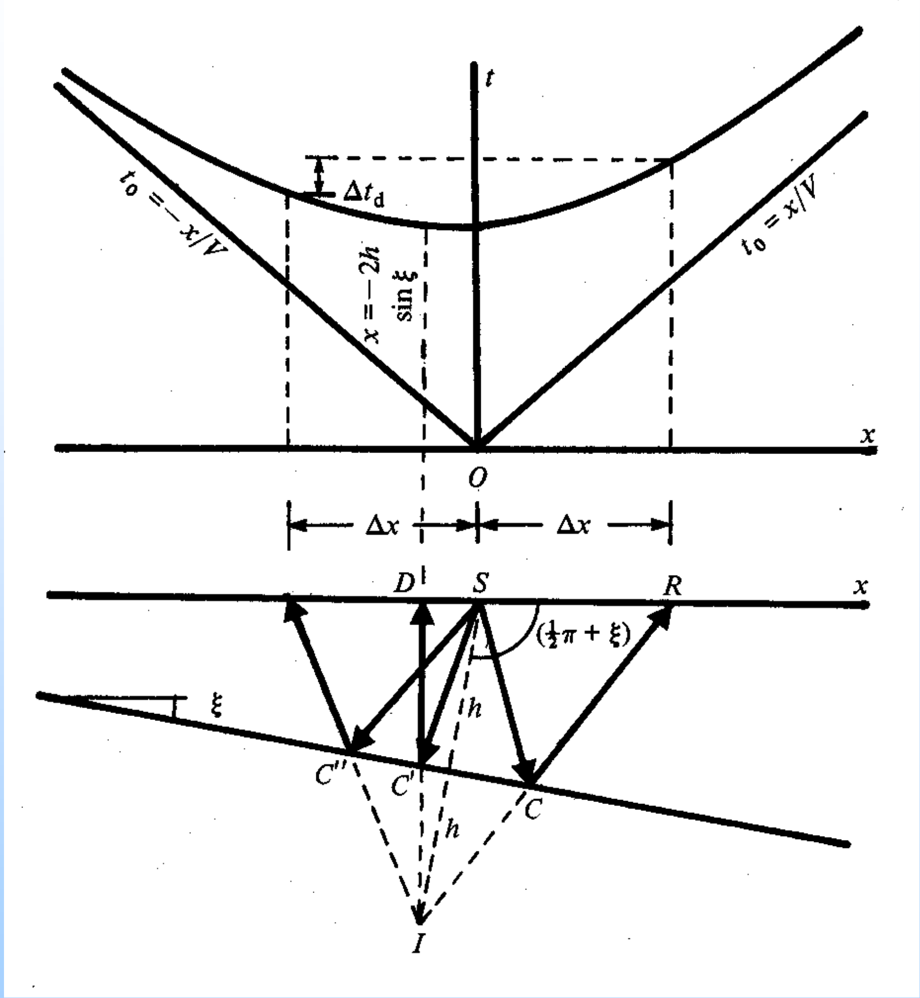
GPR:
Dip Move Out

$$v^2 t^2 = IR^2 =$$

$$= x^2 + 4h^2 - 4hx\cos\left(\frac{\pi}{2} + \xi\right) =$$

$$= x^2 + 4h^2 + 4hx\sin\xi$$

$$\frac{v^2 t^2}{(2h\cos\xi)^2} - \frac{(x + 2h\sin\xi)^2}{(2h\cos\xi)^2} = 1$$



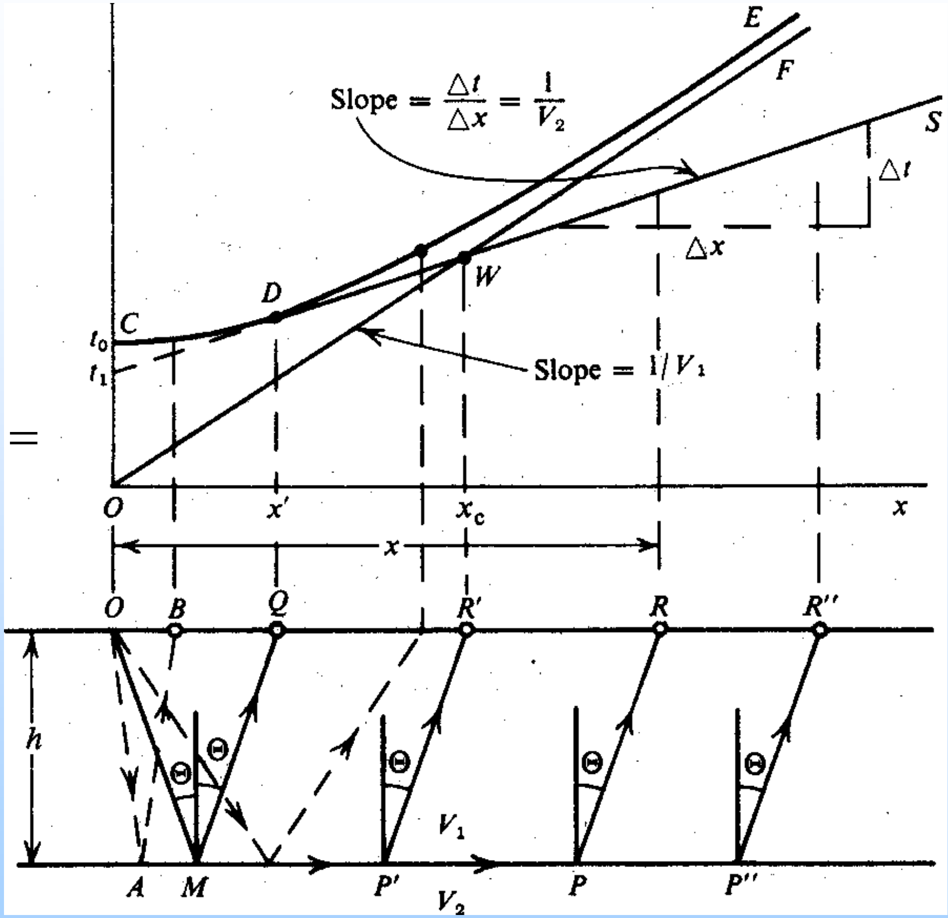
GPR:
onde rifratte

$$t = \frac{OM}{v_1} + \frac{MP}{v_2} + \frac{PR}{v_1} =$$

$$= \frac{MP}{v_2} + 2\frac{OM}{v_1} = \frac{x - 2h\tan\Theta}{v_2} + \frac{2h}{v_1\cos\Theta} =$$

$$= \frac{x}{v_2} + \frac{2h}{v_1\cos\Theta}\left(1 - \frac{v_1}{v_2}\sin\Theta\right) =$$

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

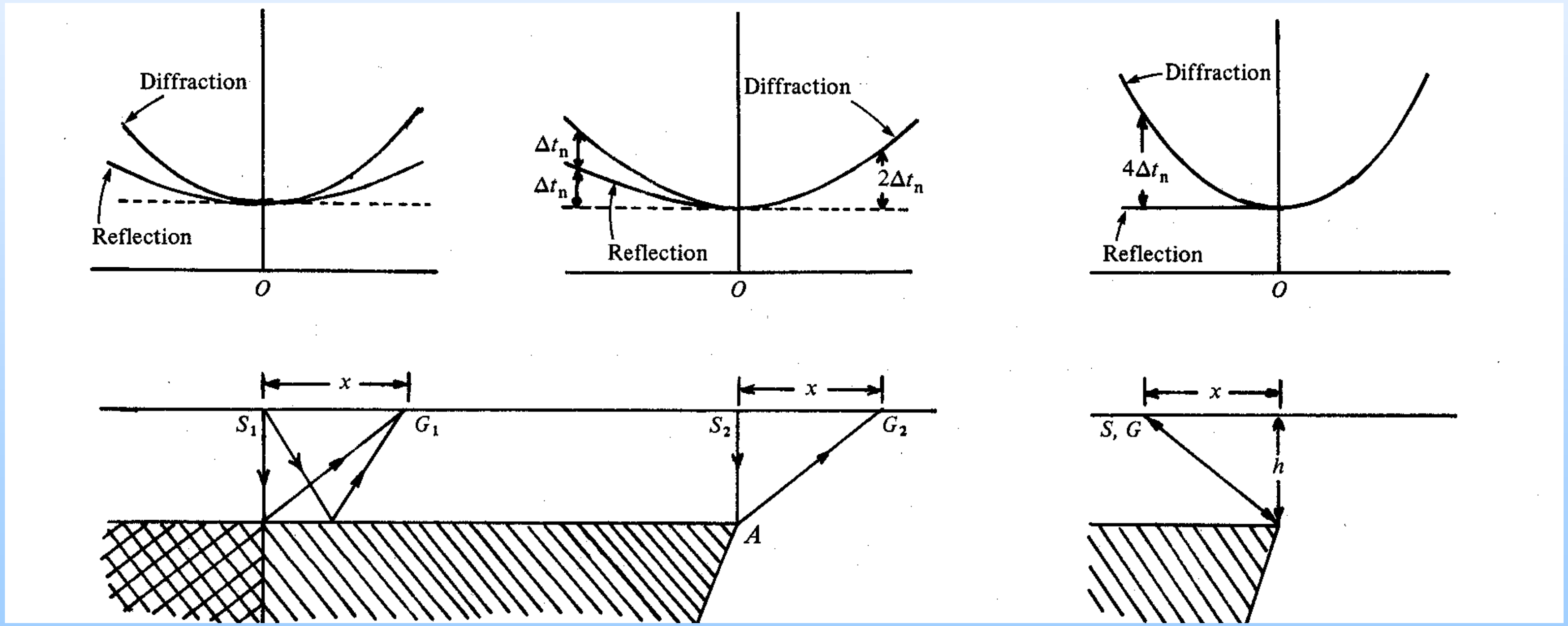


GPR:
onde diffratte

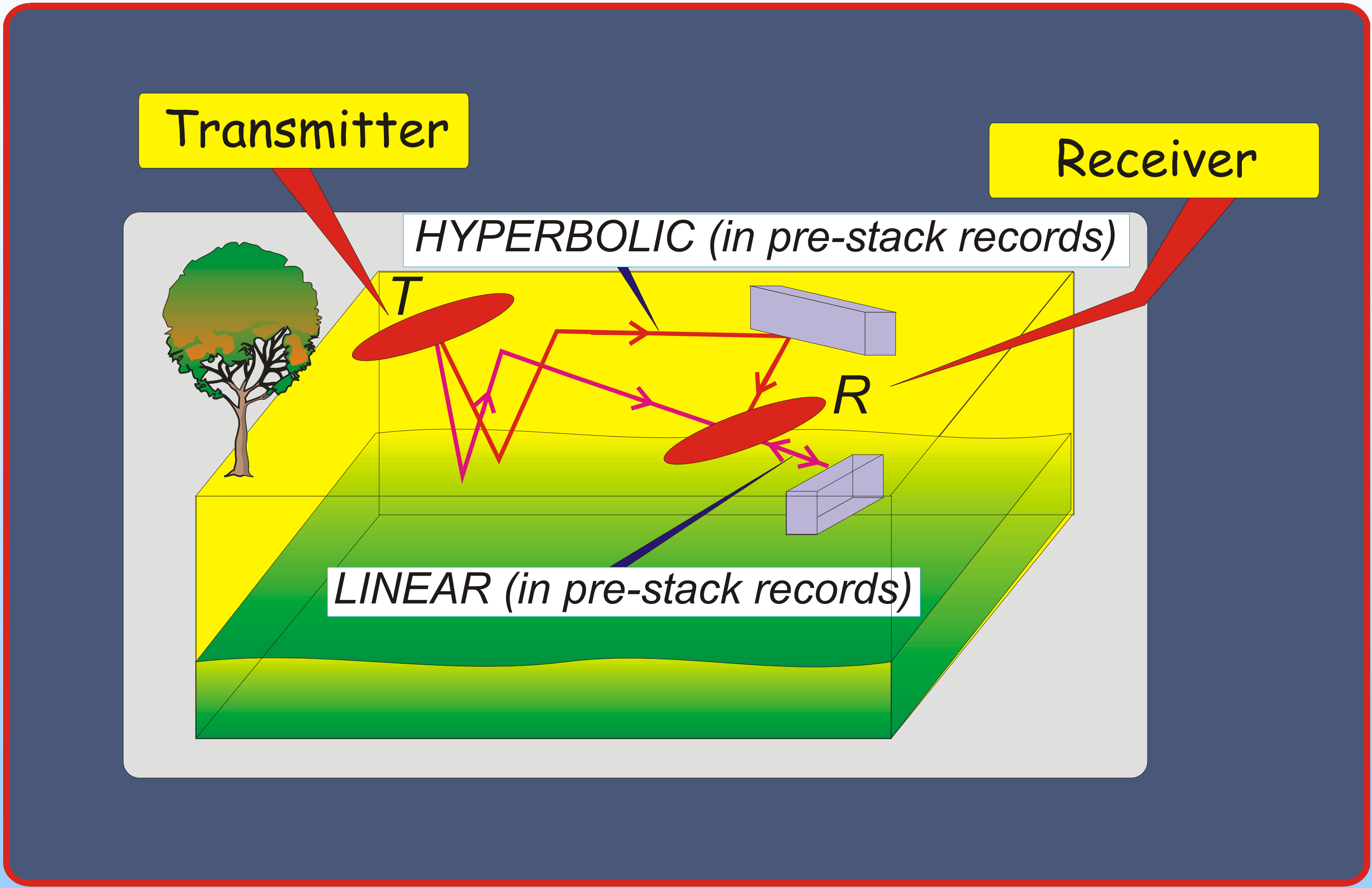
$$t_r = \frac{1}{v}\left(x^2 + 4h^2\right)^{\frac{1}{2}} \approx \frac{2h}{v} + \frac{x^2}{4vh} = t_o + \Delta t_n$$

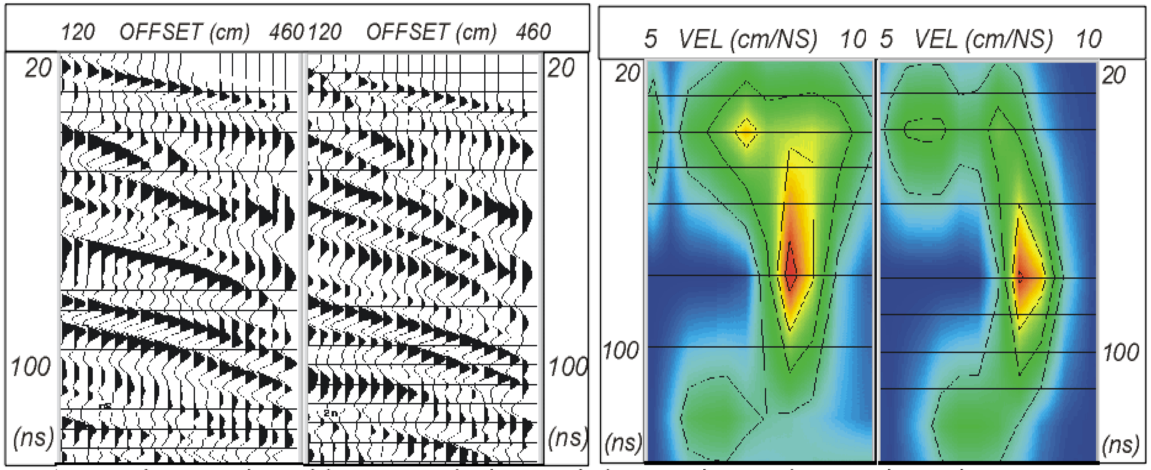
$$t_d = \frac{1}{v}\left[h + \left(x^2 + h^2\right)^{\frac{1}{2}}\right] \approx \frac{2h}{v} + \frac{x^2}{2vh} =$$

$$= t_o + 2\Delta t_n =$$

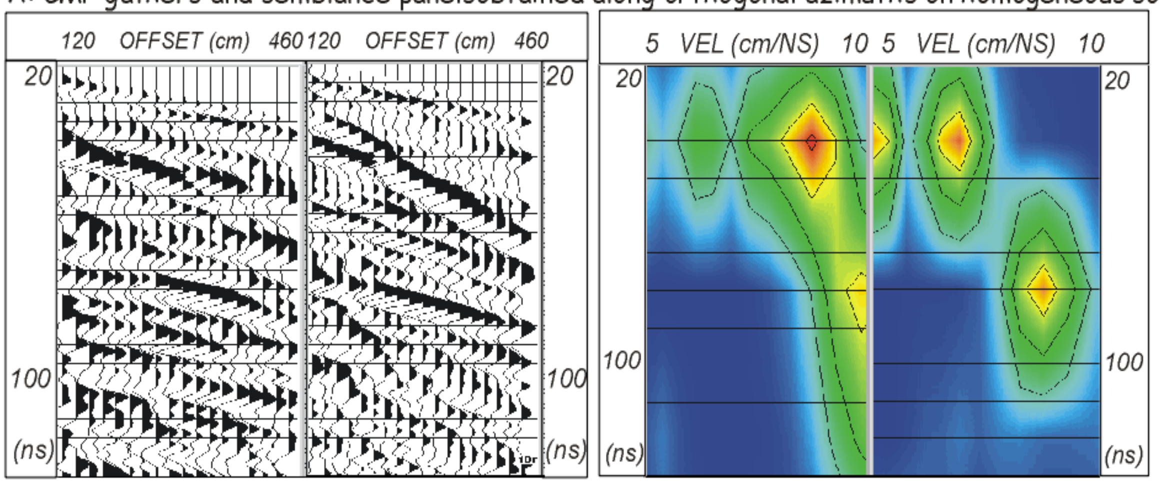


GPR:
onde laterali





A: CMP gathers and semblance panelsobtained along orthogonal azimuths on homogeneous soil



B: CMP gathers and semblance panels obtained along orthogonal azimuths across shallow and elongated target (see text for details)

- Scheme of 3D CMP
- data acquisition