MULTIPLE

multiples **or** ***secondary reflections***

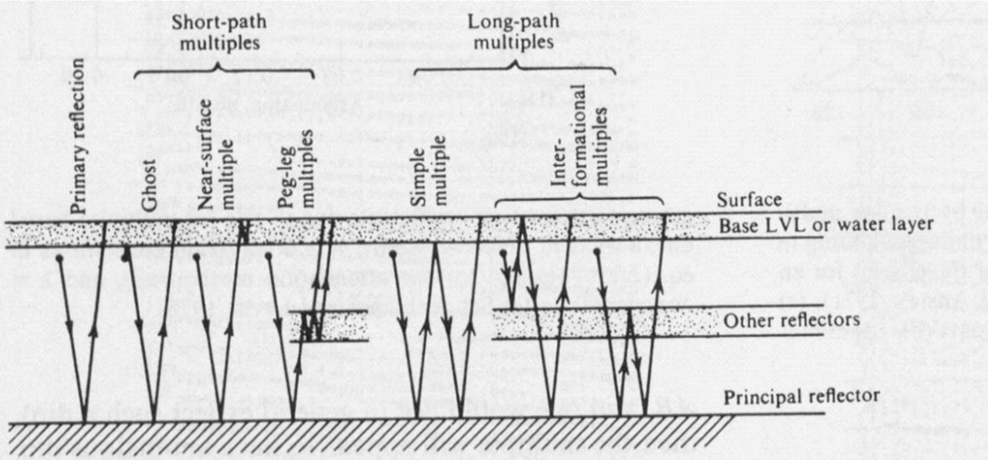


Fig. 6.29 Types of multiples.

Table 3.1 *Energy reflected at interface between two media*

Interface	First medium Velocity	First medium Density	Second medium Velocity	Second medium Density	Z_1/Z_2	R	E_R
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 botom	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^3; the minus signs indicate 180° phase reversal.

Multiples are apparent reflectors due to "multiple" or repeated paths of the seismic waves inside the crossed thicknesses

Main discontinuities cause presence of multiples:
they are characterized by maximum (absolute) values of the reflection coefficients

=> The sea level (to a lesser extent also the sea bottom) is the best candidate to create multiples

One of the first interpretation step is to recognize the multiples. They are signals that are to be classified in the seismic profiles and distinguished from the primary signals,
that describe the real (in twt) geometries of the deep strata.

The paths of the seismic waves (also that ones that produce multiples signals) generally are represented by oblique paths within the reflecting discontinuties. Anyway, the horizontal components of the seismic profiles are smaller than vertical components.

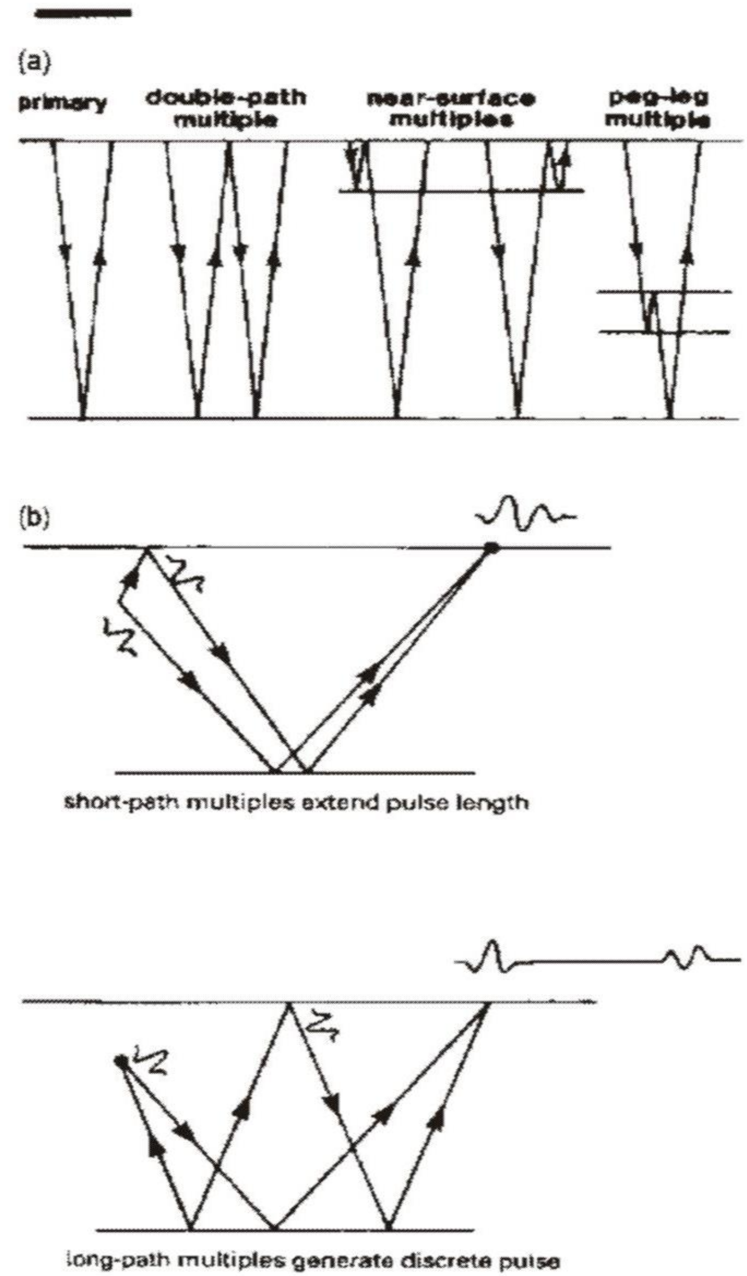
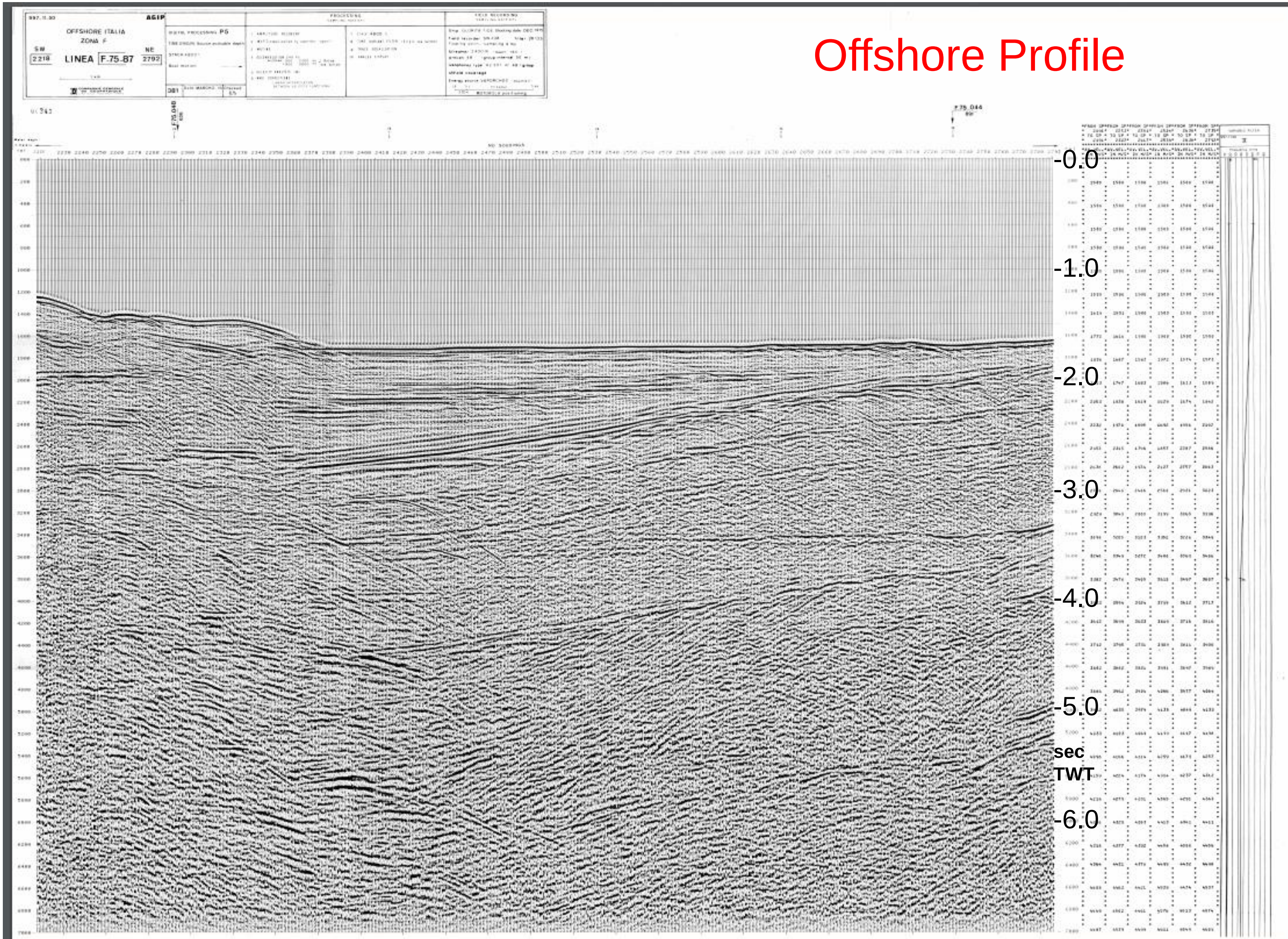


Fig. 4.5 (a) Various types of multiple reflection in a layered ground. (b) The difference between short-path and long-path multiples.

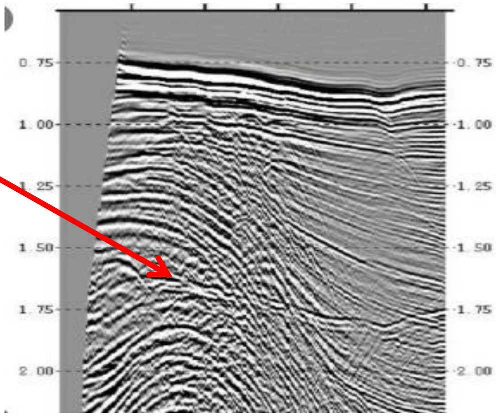
Offshore Profile



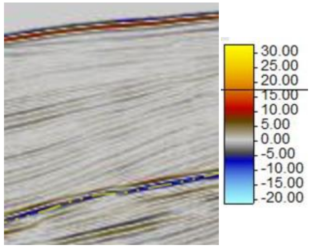
Generally **multiples** are characterized and can be recognized, by:

- **depths,** depending on their travel; their deepening will be the summation of the deepening of the reflectors that produced them;

- **frequencies,** that are higher than primary reflection frequencies at the same twt depths;



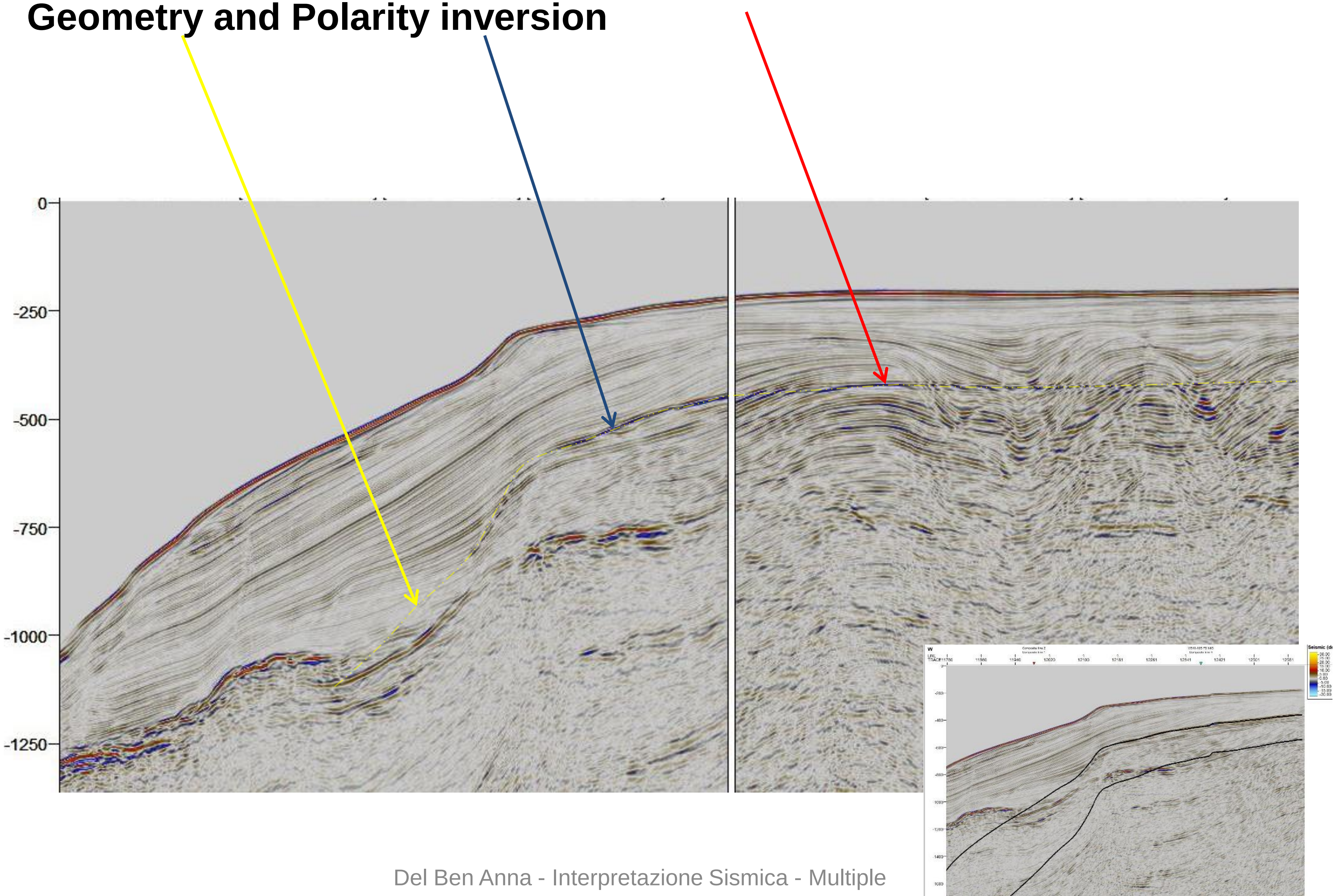
- **polarity inversion;**



- sometimes, several **diffraction** hyperbola due to *stack* velocity pertinent to primary reflectors, don't be appropriate to horizontalize the multiples signals during the *stacking* process;

- **smaller velocities,** in the velocity semblance, than primary reflectors at the same twt depths.

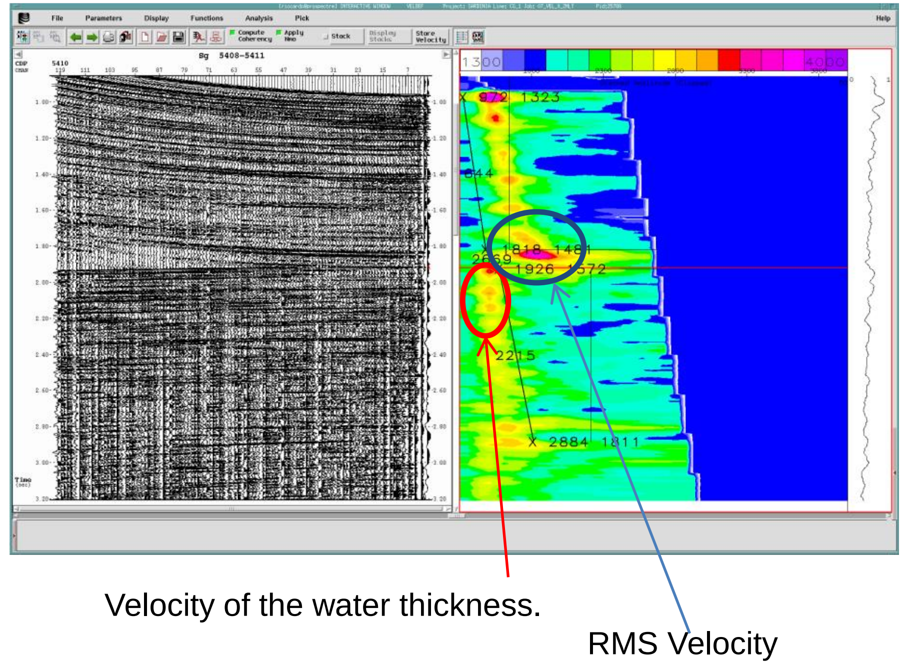
Geometry and Polarity inversion

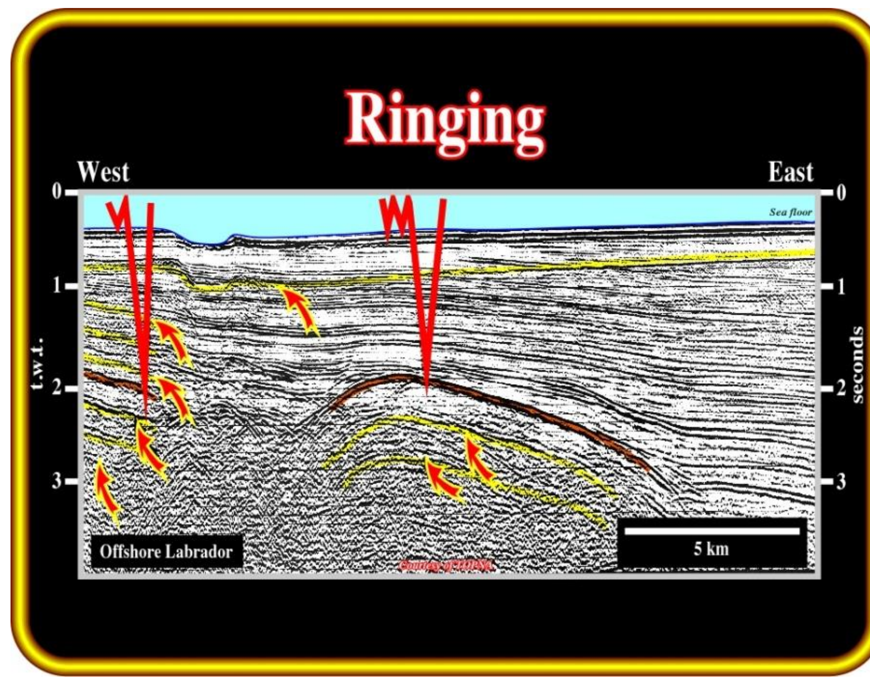


The reflected energy of the multiples will generally be reduced by *standard processing:* if we correctly select the *stack velocities* in the semblance, the horizontal alignment of the multiple reflections will be reduced and the stacked signal will decrease.

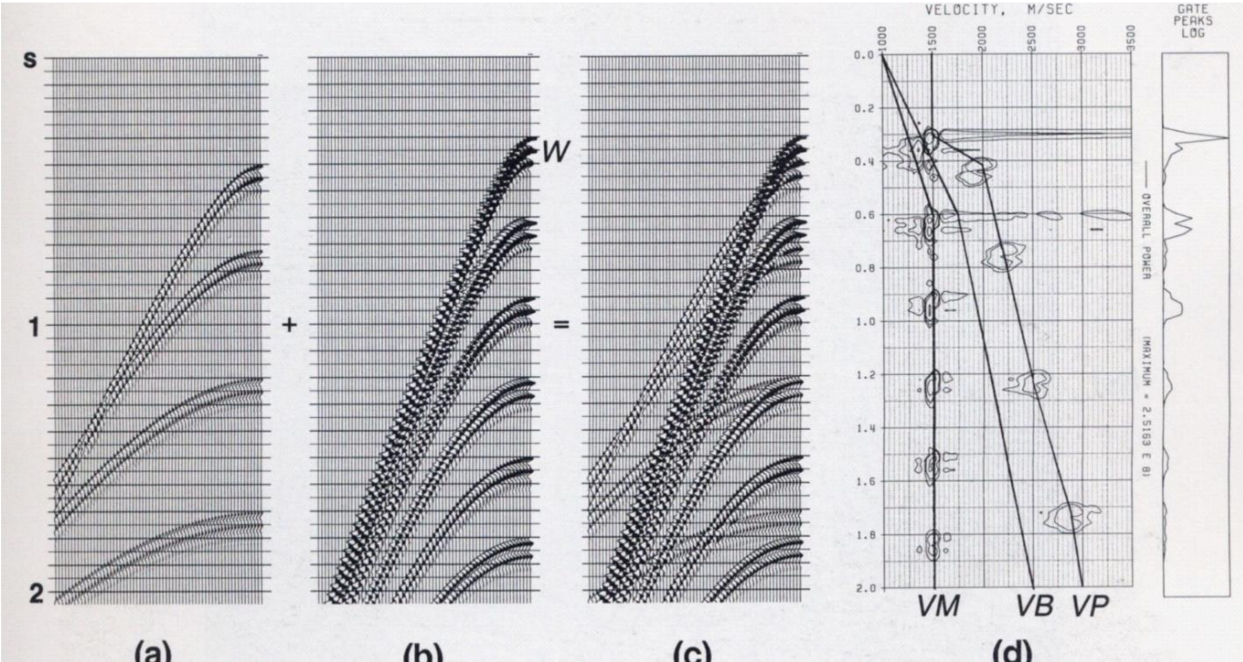
Both the <u>frequency and velocity</u> parameters could be useful during *processing* to eliminate or almost decrease the multiples effect.

Ringing : repetition of a path within a homogeneous layer; in the example at the right, the layer is water. →





Synthetic CMP-gathers and semblance

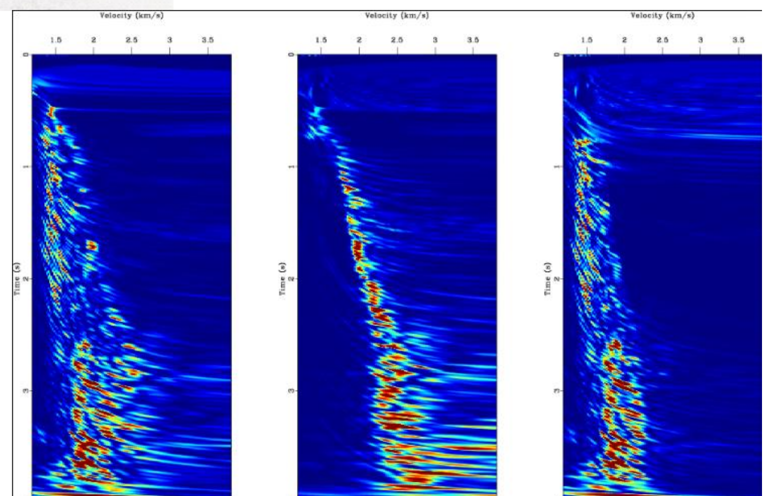


The hyperbole due to multiples are characterized by smaller velocities (therefore greater ΔT) than velocities of the primary reflectors placed at the same TWT depth.

Synthetic seismograms **related to:**

a) primary reflectors;
b) multiples: ***often they interfere with each other;***
c) composite seismogram: ***multiples normally have higher curvature than the primary reflectors;***
d) velocity spectrum.

Semblance →



Evidence of multiples in the seismic signal: how the *stacking* reduces multiples

→

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

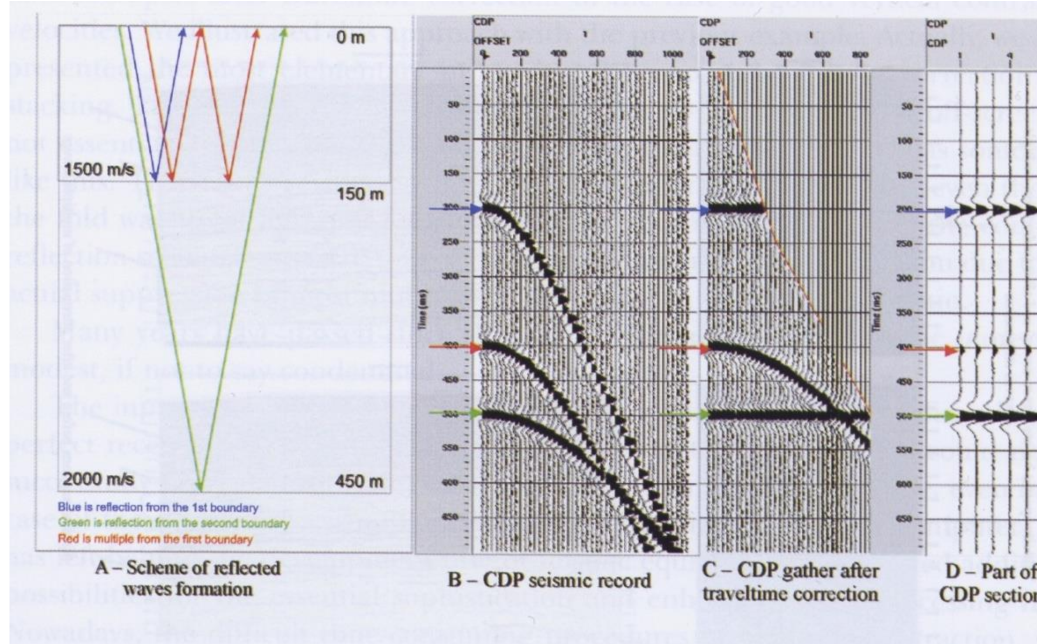
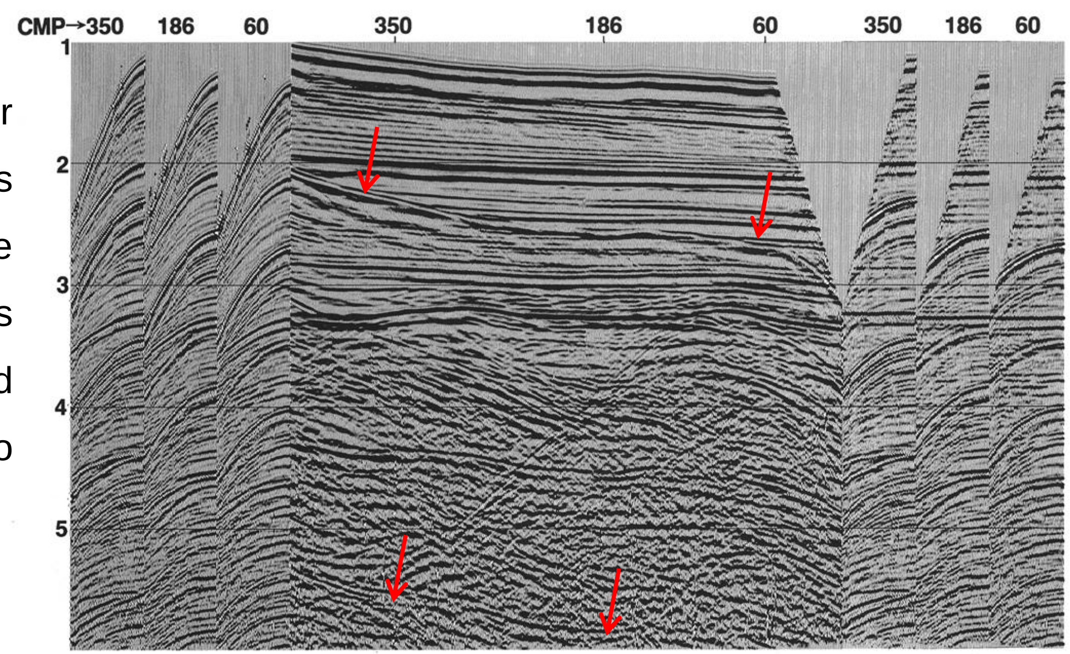


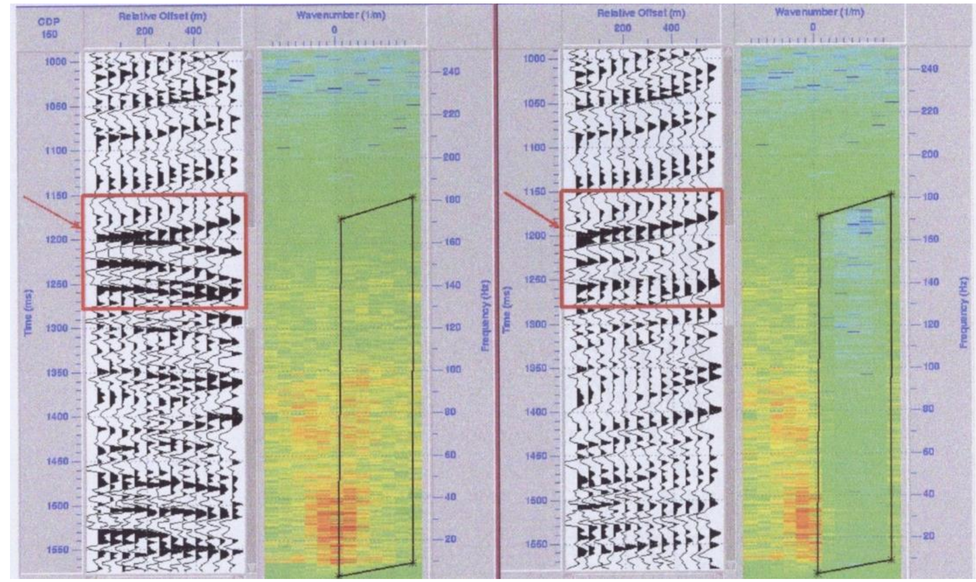
Figure 1.1: Scheme of seismic artefacts formation over the time section.

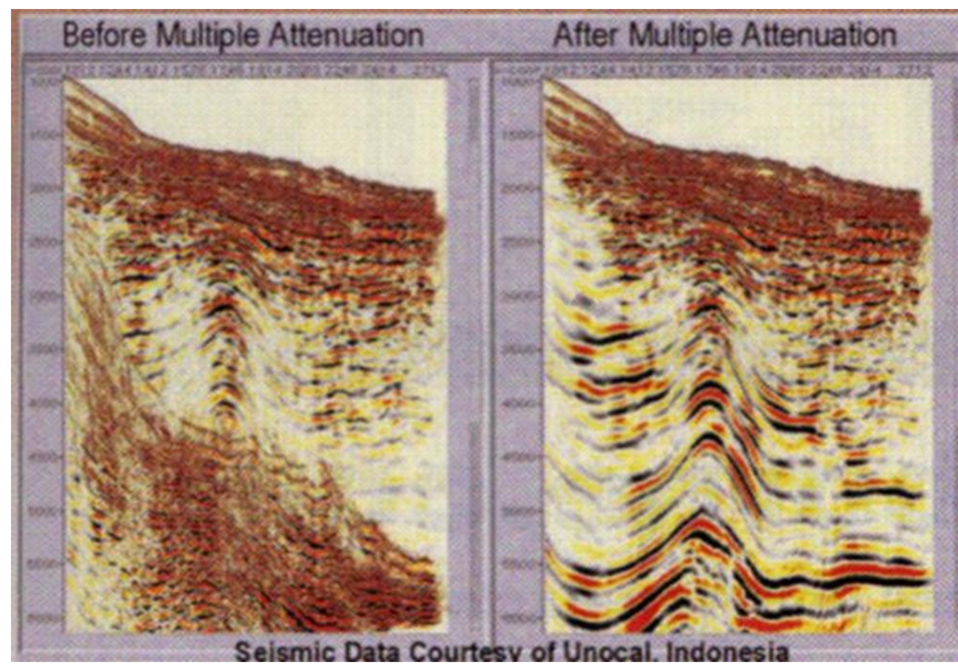
Three CMP gathers before (left) and after (right) NMO correction. Note that the primaries have been flattened and the multiples have been undercorrected after NMO correction. As a result, multiple energy has been attenuated on the stacked section (center) relative to primary energy (from Yilmaz, 2001)



Example of multiples removal:

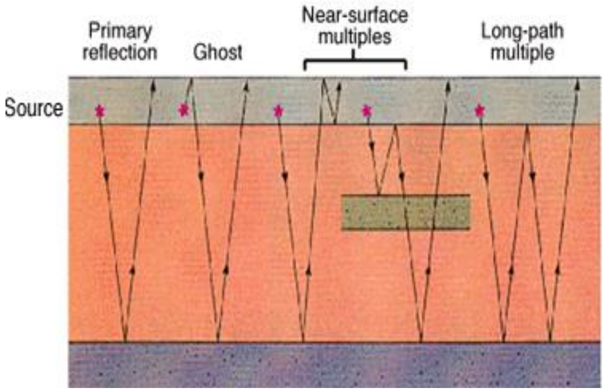
in the frequency domain we can select the multiple frequencies and eliminate them to obtain a "*demultiplexed*" profile

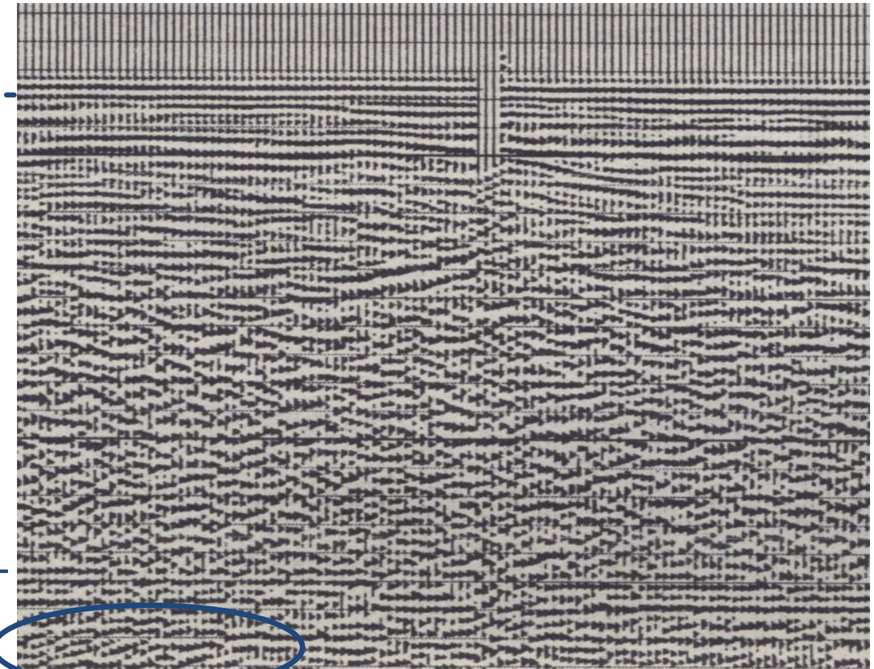




Multiples - Examples

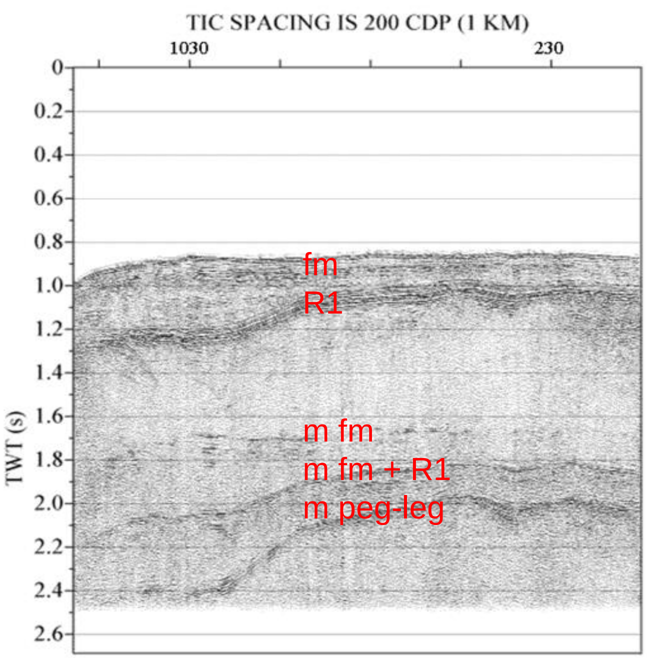
multiple “ghost” m -





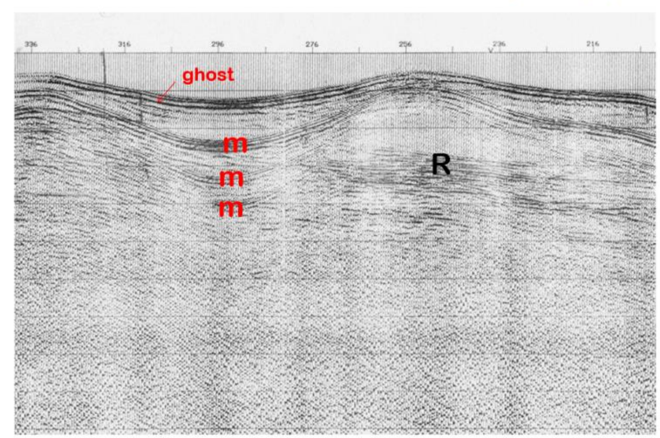
Simple multiple m –
(higher frequency)

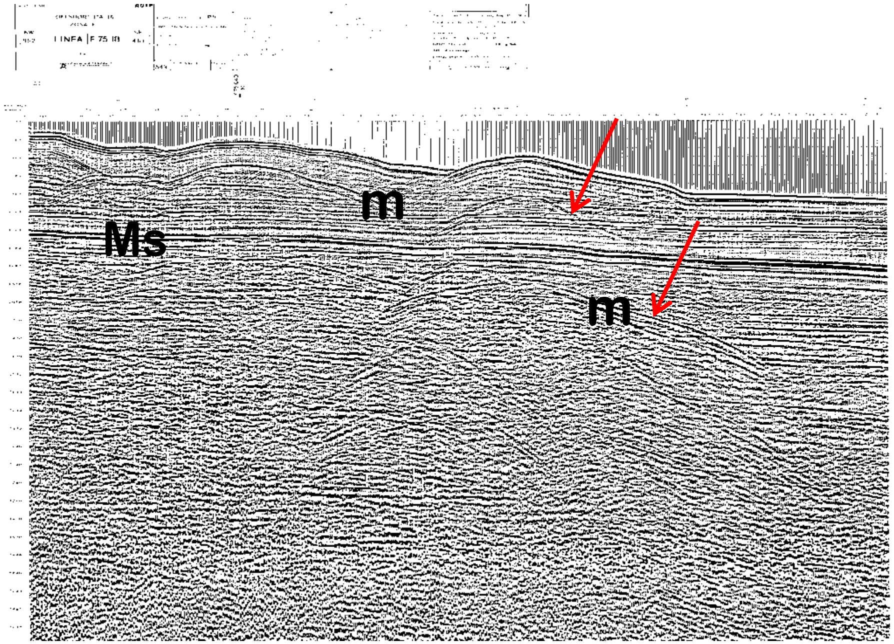
diffraction hyperbole

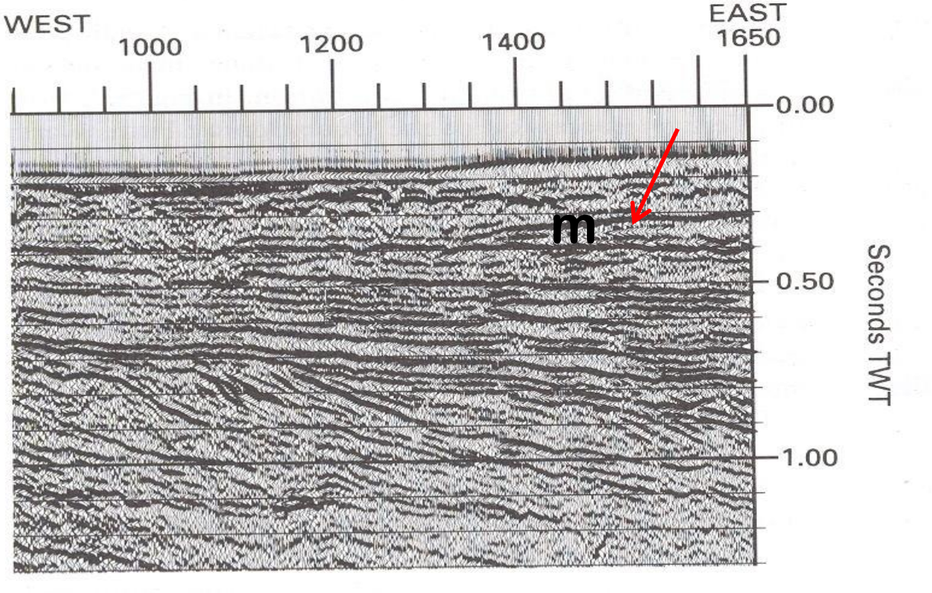


1999 Gulf of Mexico Line 7

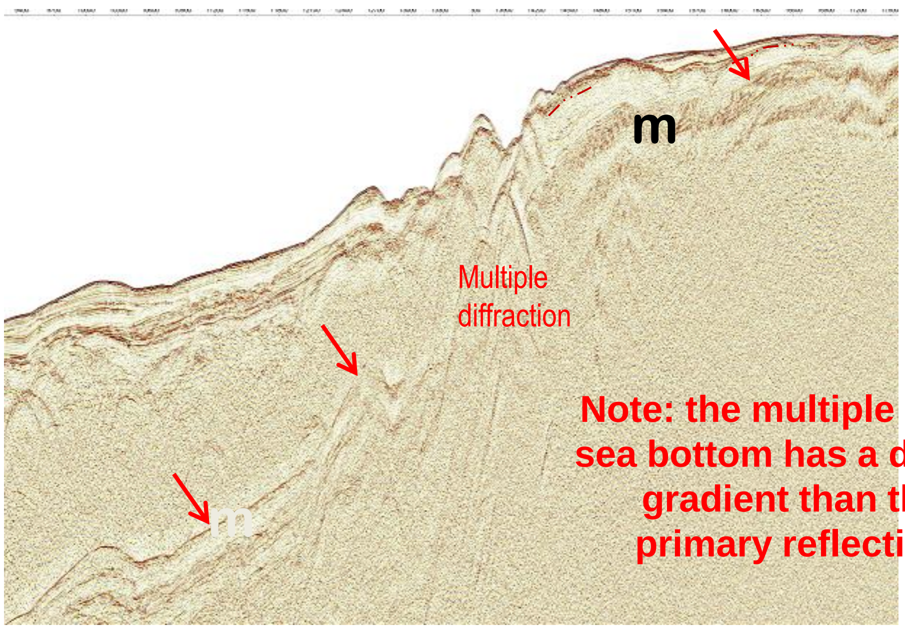
Esempio (Stretto di Messina):
il fondo mare, caratterizzato da alto coefficiente di riflessione, produce, oltre alle ghost, multiple semplici (“m”: pendenze via via crescenti con la profondità) che mascherano e/o interferiscono con i riflettori primari (“R”)

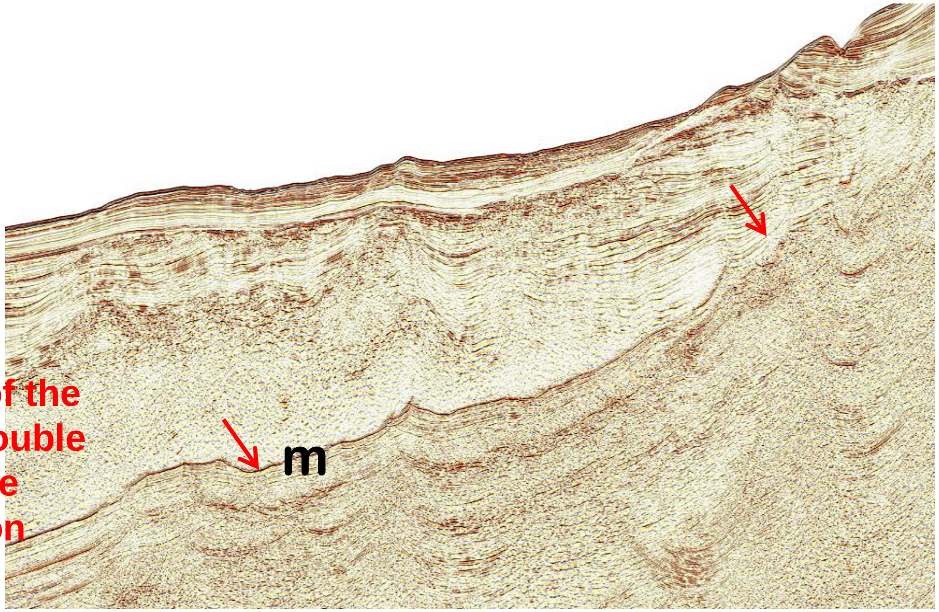




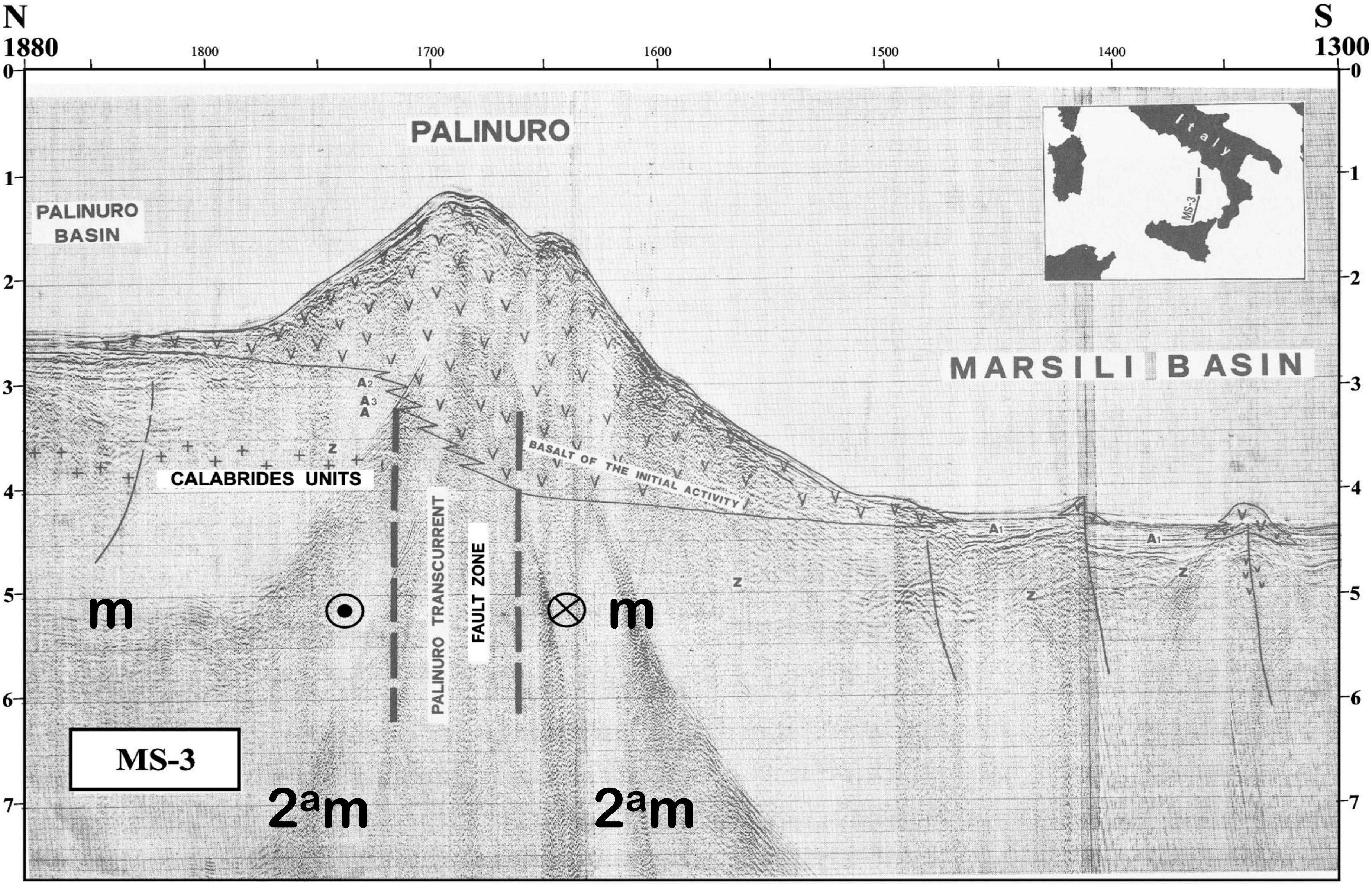


Multiples of the sea bottom: the deeper the sea bottom, the deeper the multiple





Note: the multiple of the sea bottom has a double gradient than the primary reflection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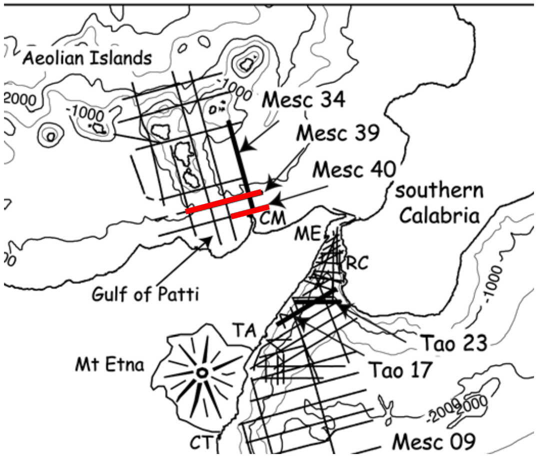
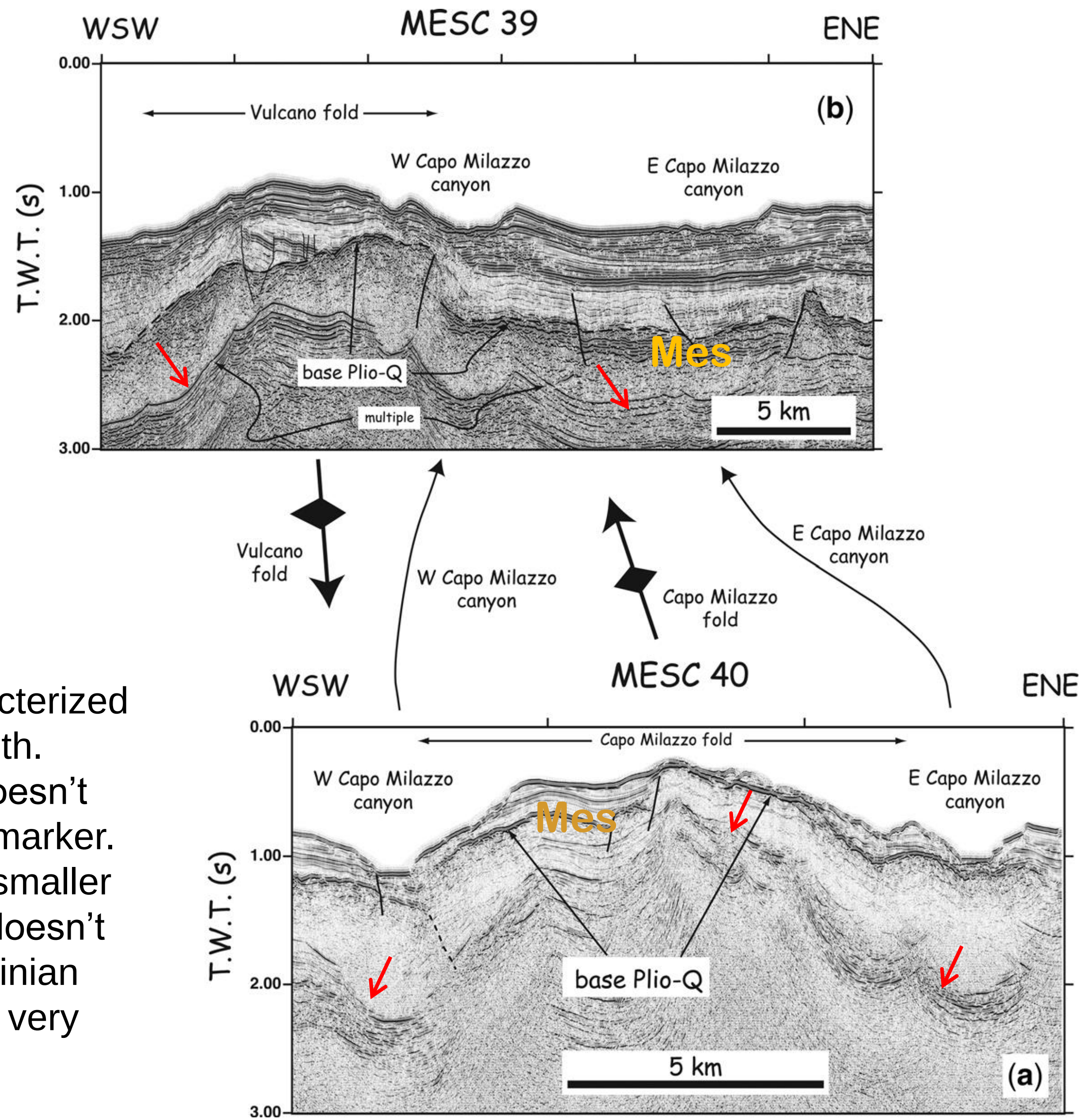
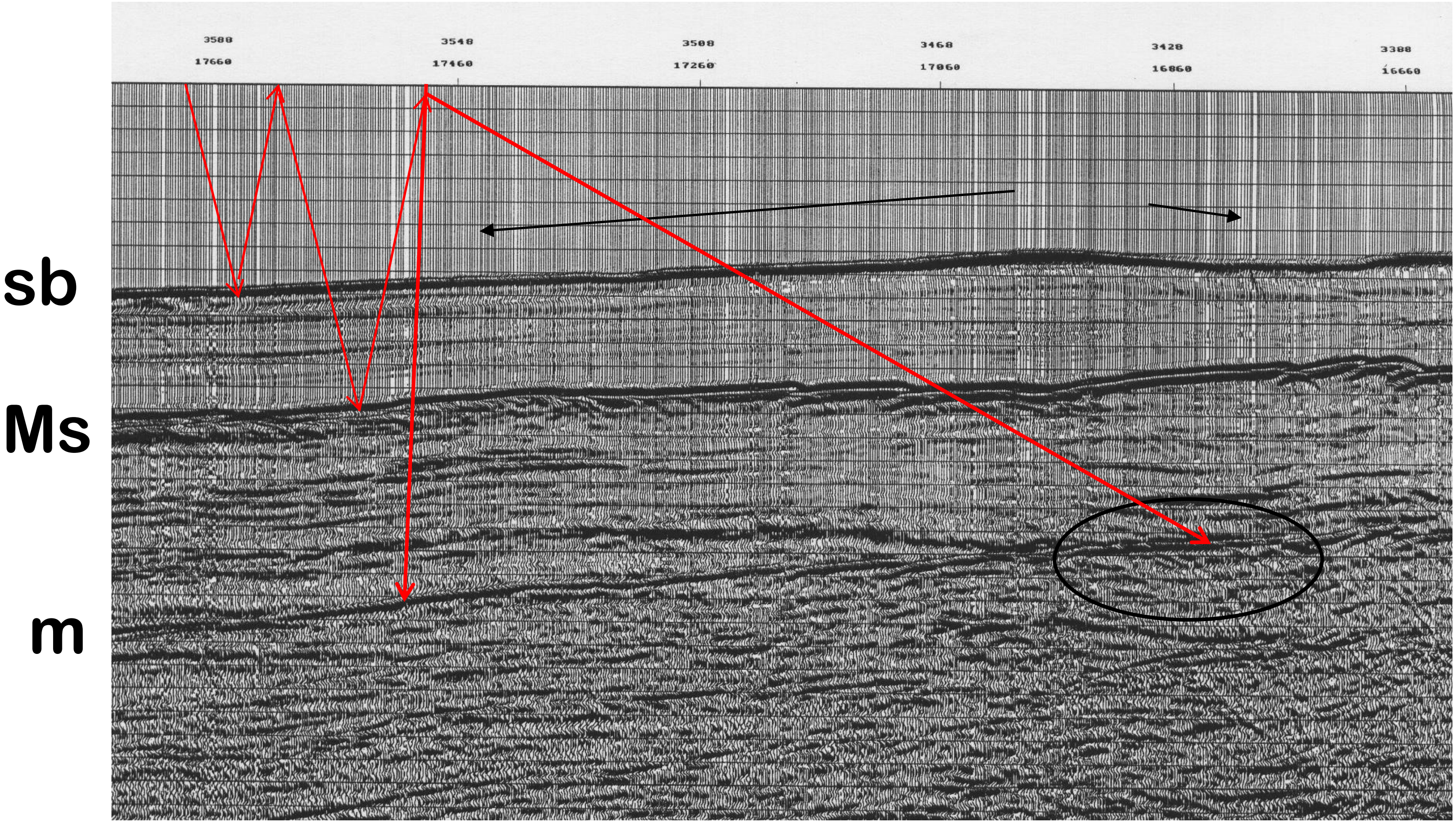
South-east Tyrrhenian Sea





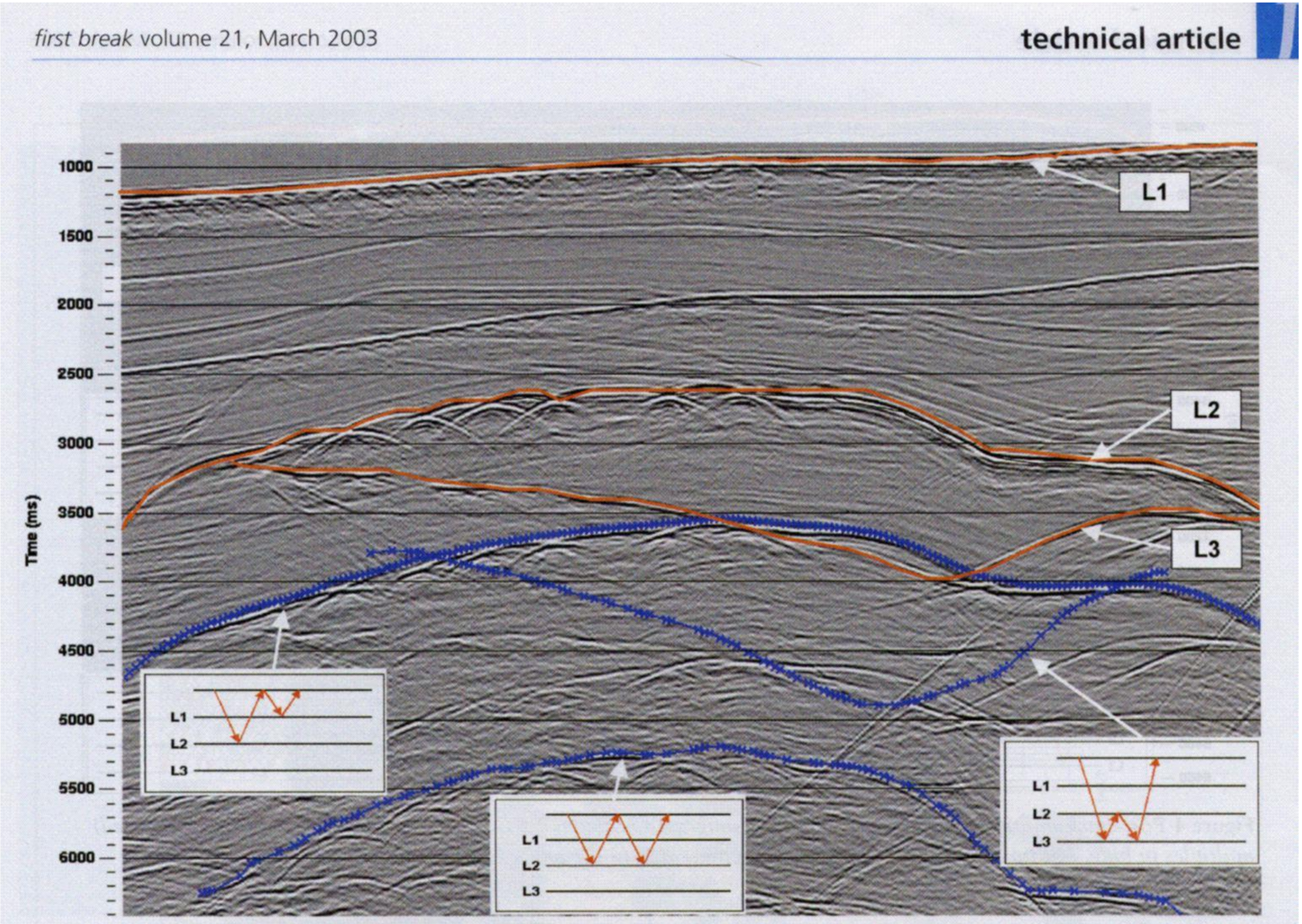
The upper profile is characterized by greater water depth.
The first multiple (↙) doesn't interfere with Messinian marker.
In the lower profile, at a smaller depth, the first multiple doesn't interfere with the Messinian marker because this is very shallower.

Example of a profile with a multiple reflector (E-Ionian Sea)



- The main multiple has been produced by Ms + sea bottom. In the circle it is noted that the inclination of the multiple becomes less than that of the Ms, due to the sum of the opposite inclinations of the primar signals.

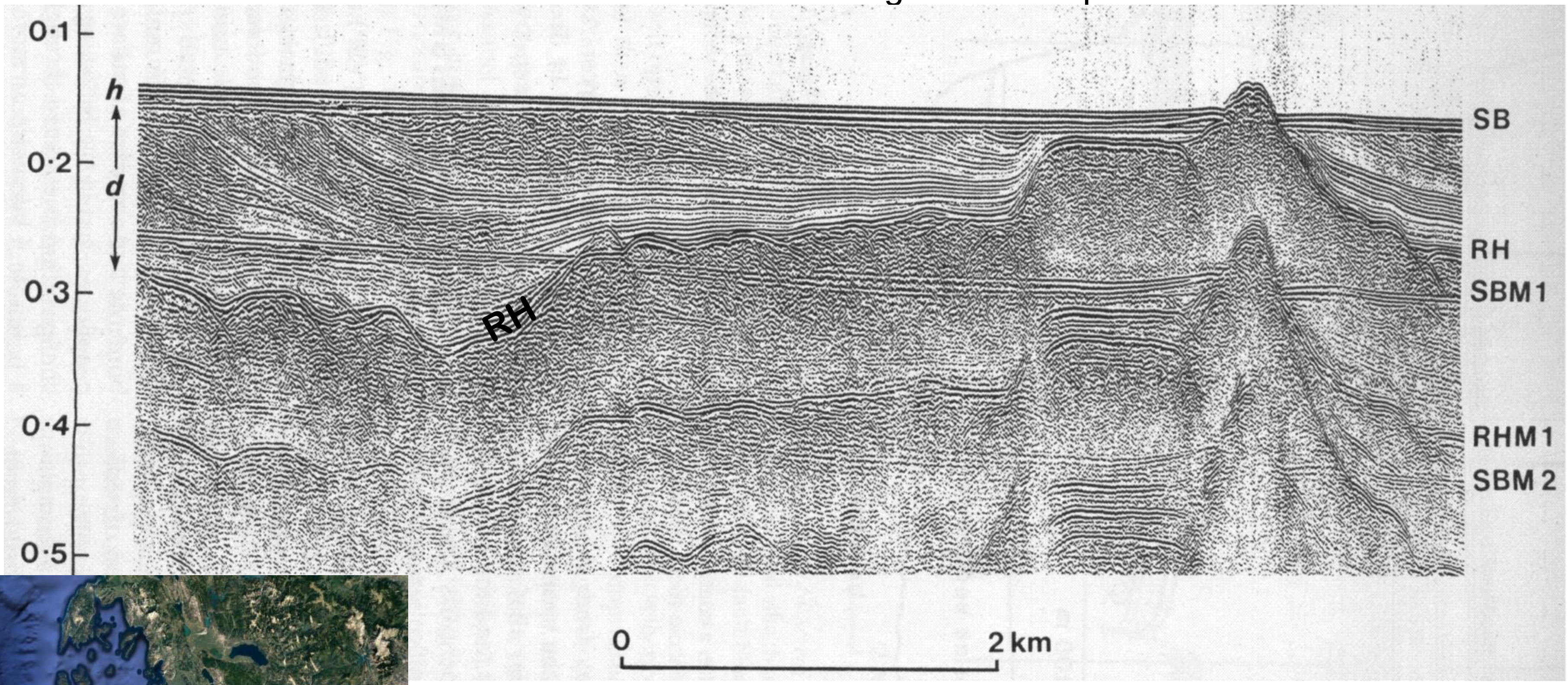
Different types of Multiples – note the deepening of reflectors

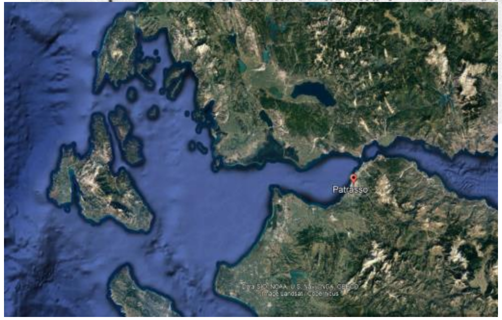


In orange the primary reflectors, in blue the multiple reflectors. One of the evidenced multiple paths is partially wrong: what is it? what is the correct path?

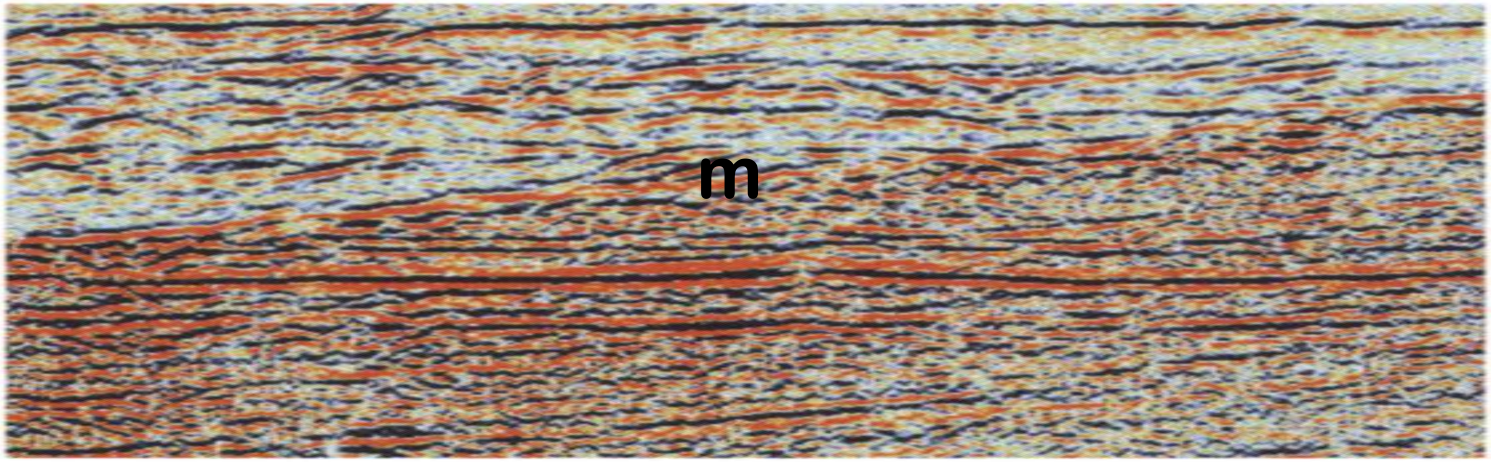
Example of multiples in a sparker profile (Patrasso Gulf)

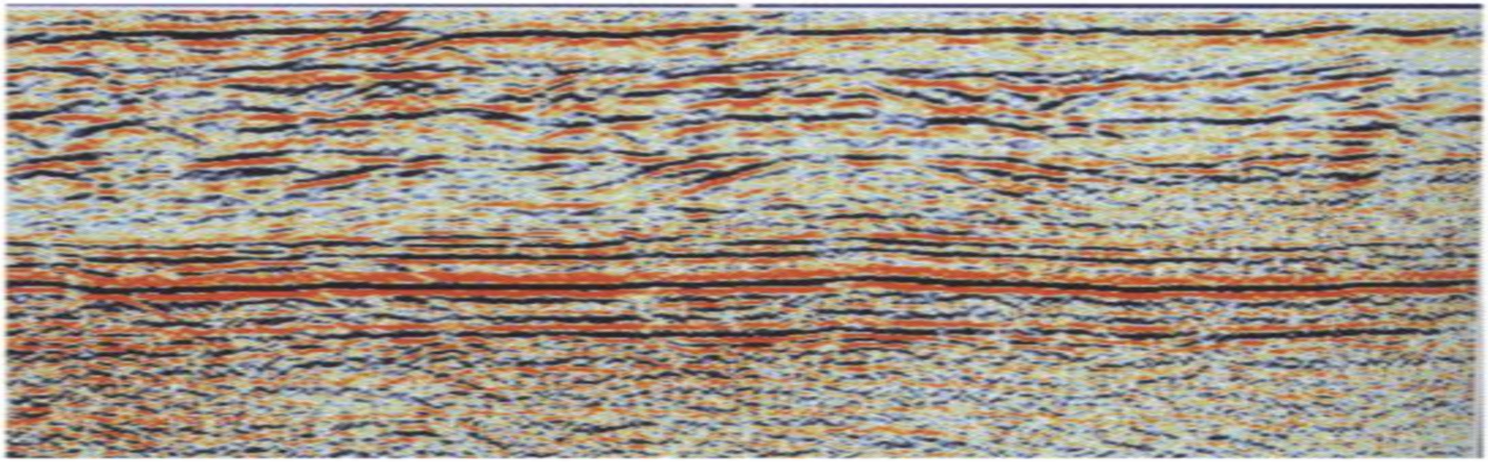
single channel high resolution profile → no NMO correction
→ multiples have been not reduced by processing,
→ multiples interfer with the primary signal.
Between these, RH is a high amplitude reflectors,
which is however evident along the whole profile

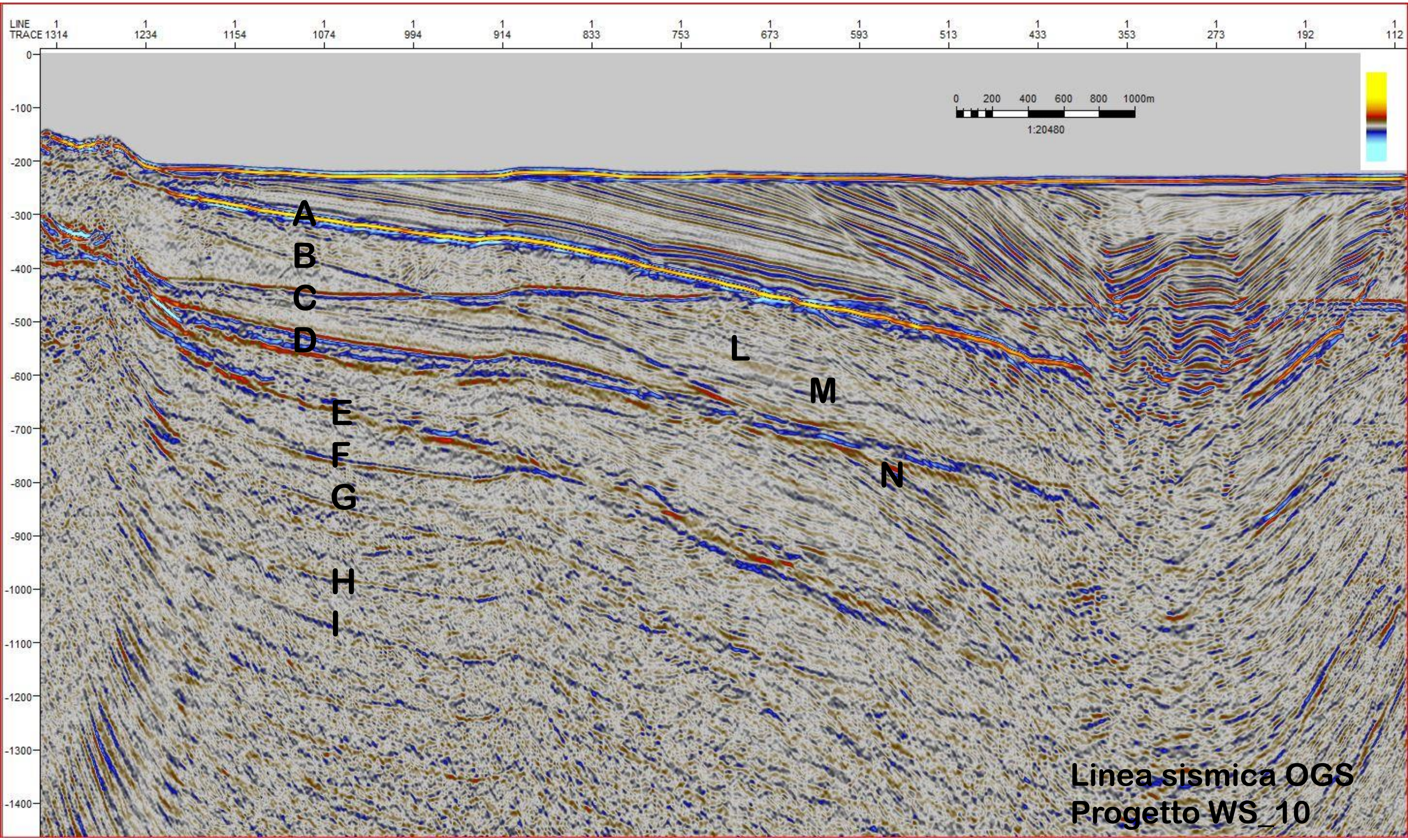




Example of multiple removal







Exercise:

What are primary and what are multiple signals?

What are the ray path that generated the multiple reflectors?

What is the real angle of the A (- PQ bottom reflector) assuming V_{PQ} = 2000m/s?