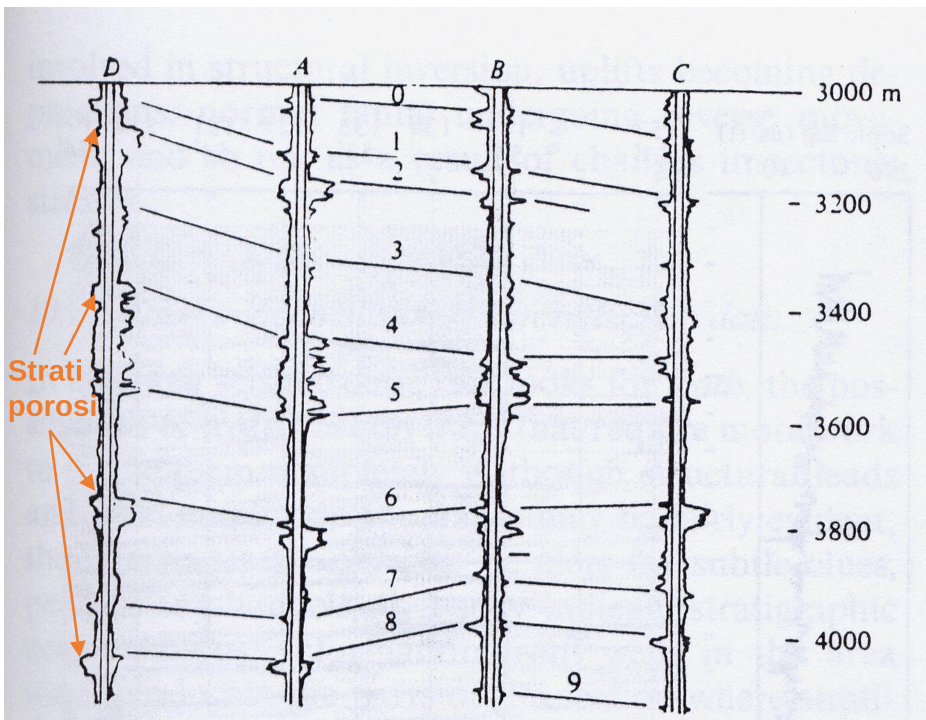
Calibration of seismic data with wells

Boreholes data, if available, are of foundamental interest for the calibration of the top and bottom of a stratigraphic sequence (*unconformities* and time duration of the corresponding *hiatus*), of its lithology and depositional environment.



Even the acquisition of geophysical data in the well provides important indications about the sequences distribution and, particularly useful, for the analysis of the *reservoirs*, of the lateral and vertical *trends* of parameters as porosity, permeability, etc.

In the example: 4 borehles record:
- Resistivity curve – on the right,
- Spontaneous Potential - on the left

Resistivity Measures

Archie Equation (1942):

$$R = a\, P^{-b} f^{-c} R_w$$

R =	measured resistivity
R_w =	water resistivity
P =	formation porosity
f =	water saturation
a,b,c =	empirical constant

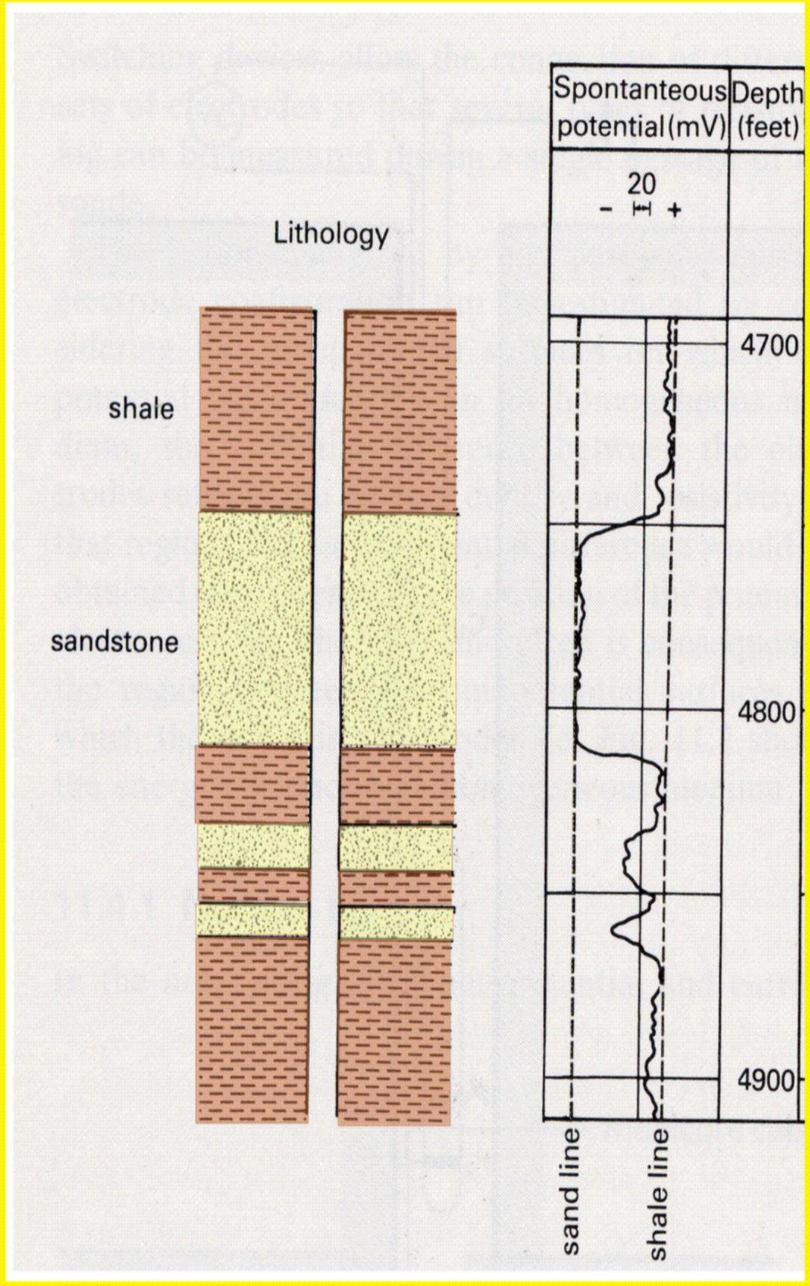
R is particularly usueful to define the possible hydrocarbon presence (high R)

Spontaneous Potential (figure)

(caused by electrochemical causes and by the mechanical activity of fluids, the prevailing control factor appears to be the flow of groundwater)

The SP anomaly depends on:
- permeability
- thickness
- resistivity

SP is particularly useful to define the sandy-clayey alternations



The *logs* generally used for correlations with seismic data are: GR (*Gamma Ray,* exploits natural radioactivity), *density logs (Gamma Ray source), sonic log, dipmeter (measures strata slope with 4 resistivity electrodes).*

The seismic stratigraphy integrates information from seismic, drilling, well logs and, often, outcrops. It also allows us to predict the presence and regional distribution of reservoirs such as, for example, turbidity within a proximal marine area.

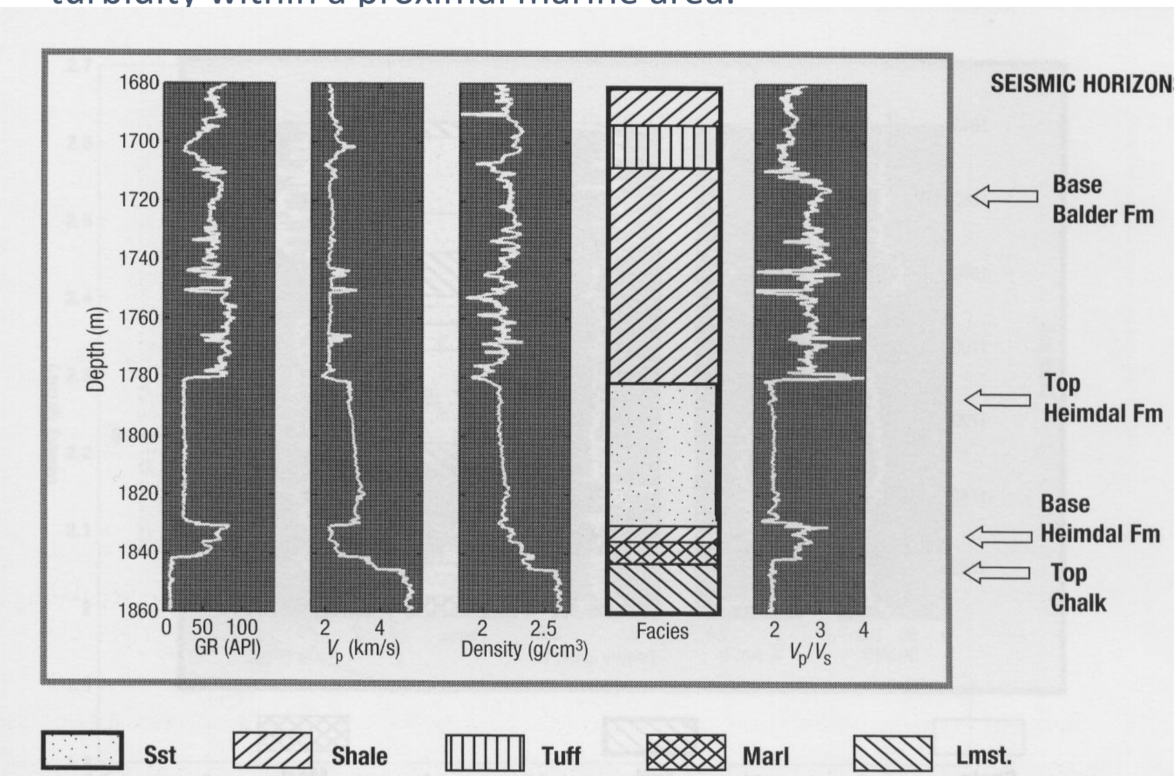


Figure 5.43 Various log data and facies in Well 1, the type-well. Facies observations are from cores. Key seismic horizons are noted.

The integration with the seismic data allows to define the different geological and tectonic phases that determined the lateral variations of thickness, lithology, porosity, etc.

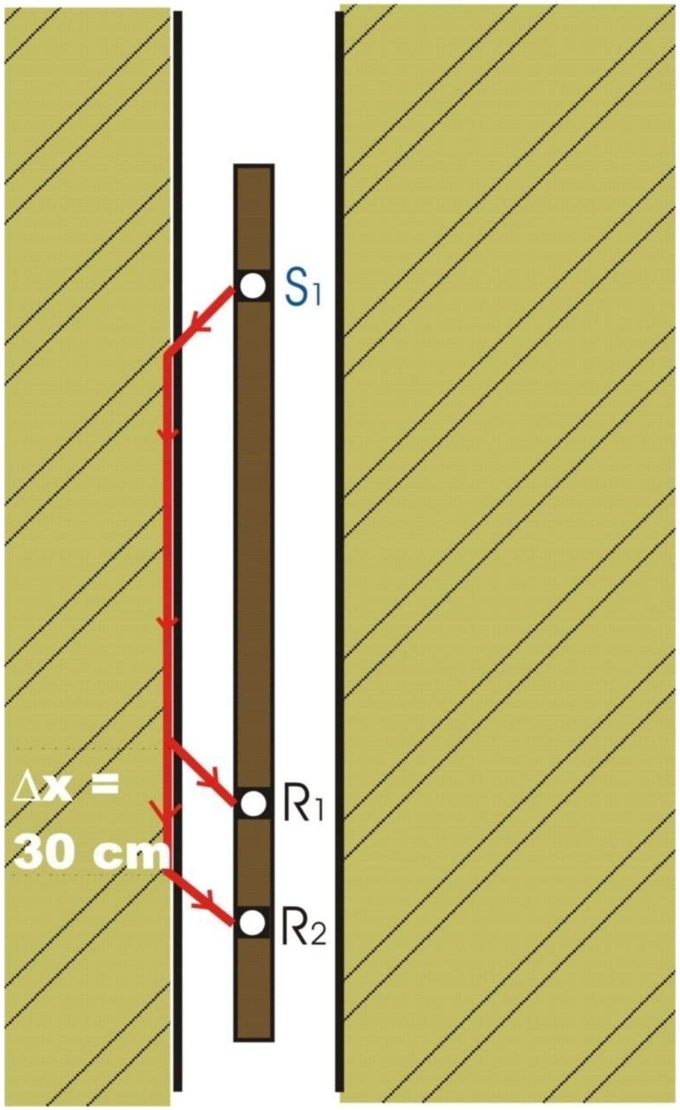
Above all, it allows to extrapolate the information produced by well to the entire investigated area or, at least, to the surrounding area.

Sonic Log

In seismic interpretation, correlation between geological and geophysical data from wells (expressed as a function of depths in meters) and reflections (expressed as a function of depth in TWT) represents a critical step.

Correlations between depth in meters (measurement of the depths reached by the well) and depths in TWT (depths reached by the P waves) can be exactly done there is availability of a Sonic Log, which provides the measurement of the characteristic velocities of every single thickness crossed.

If distribution of velocities as a function of depth is known, the conversion becomes automatic and precise.

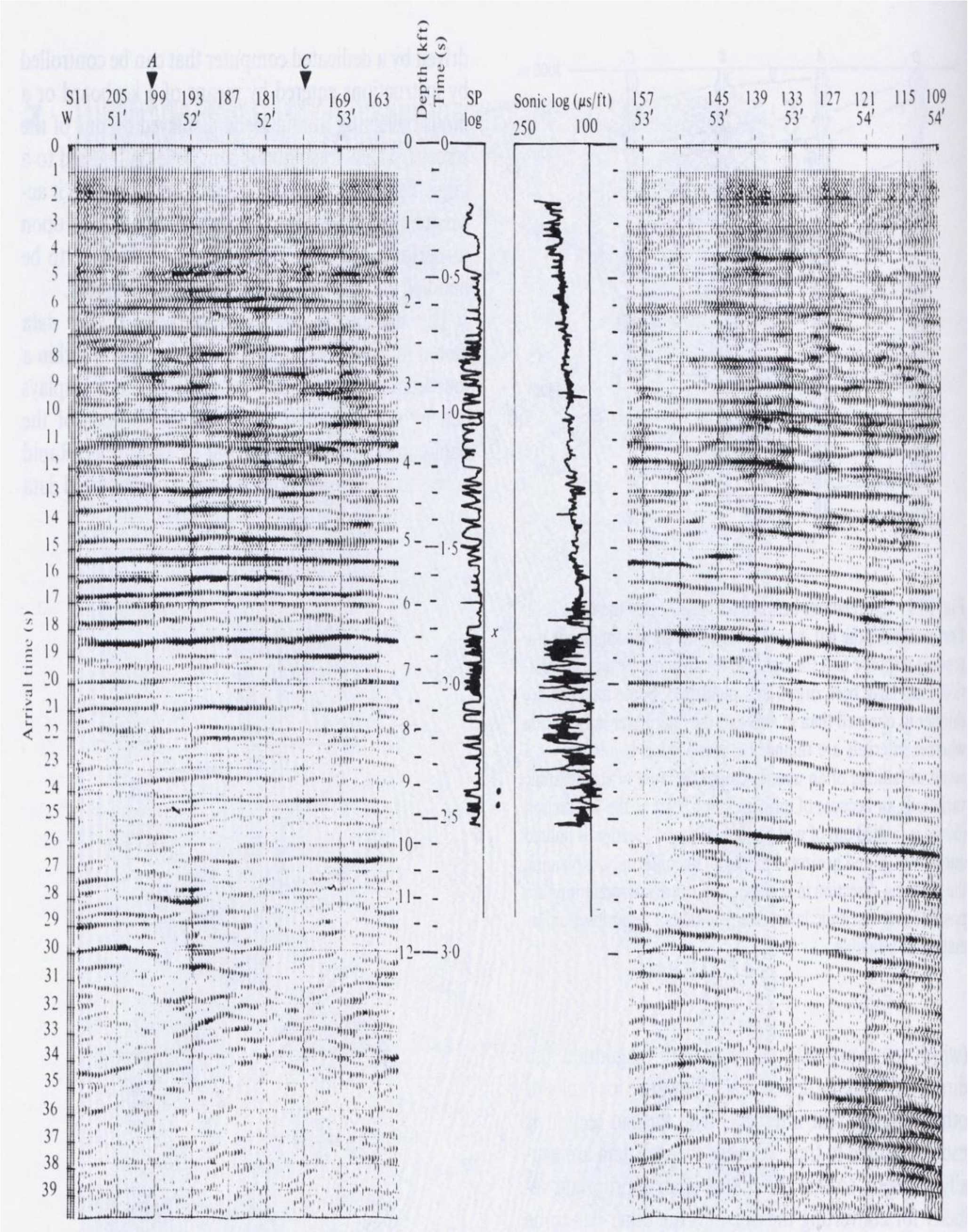


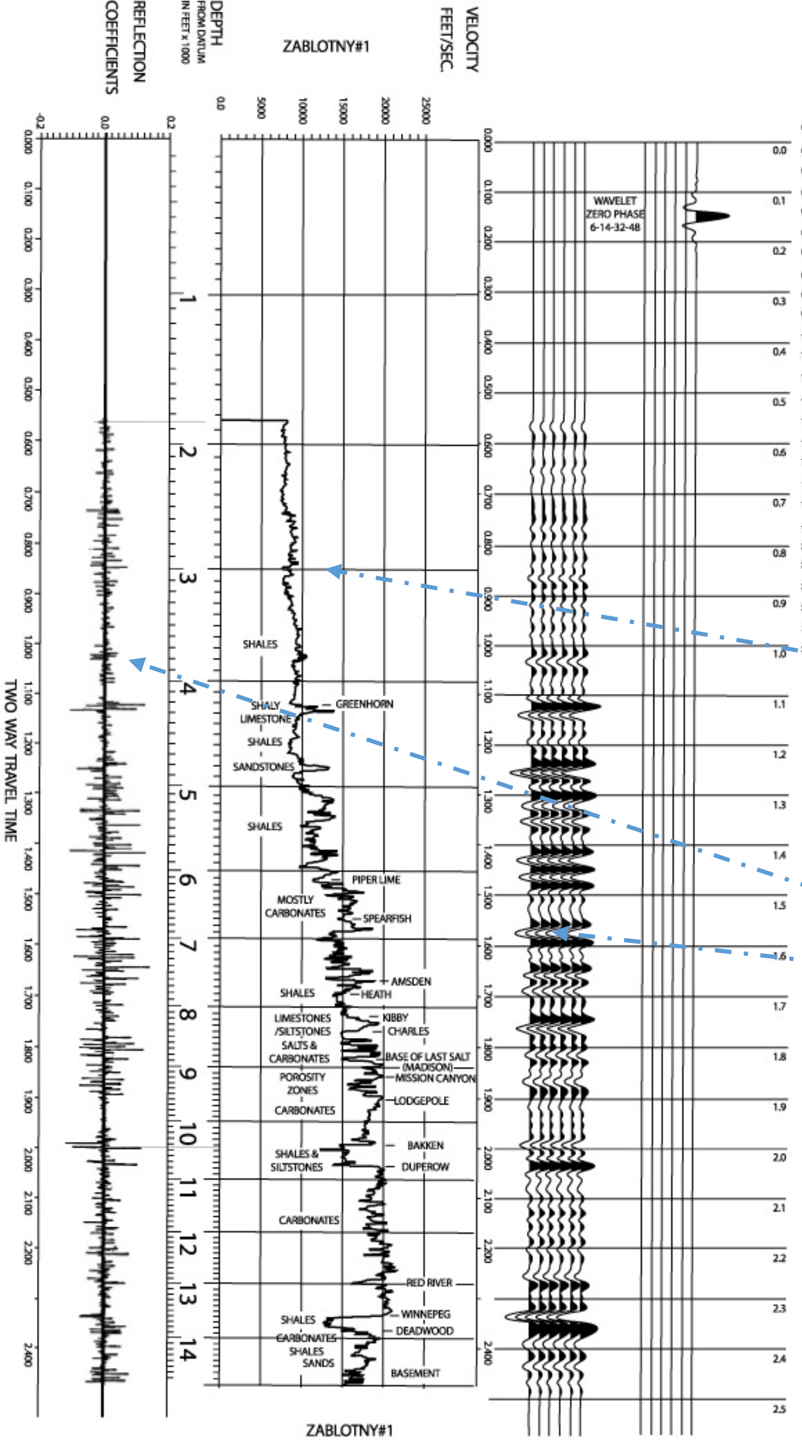
Calibration of seismic data with wells

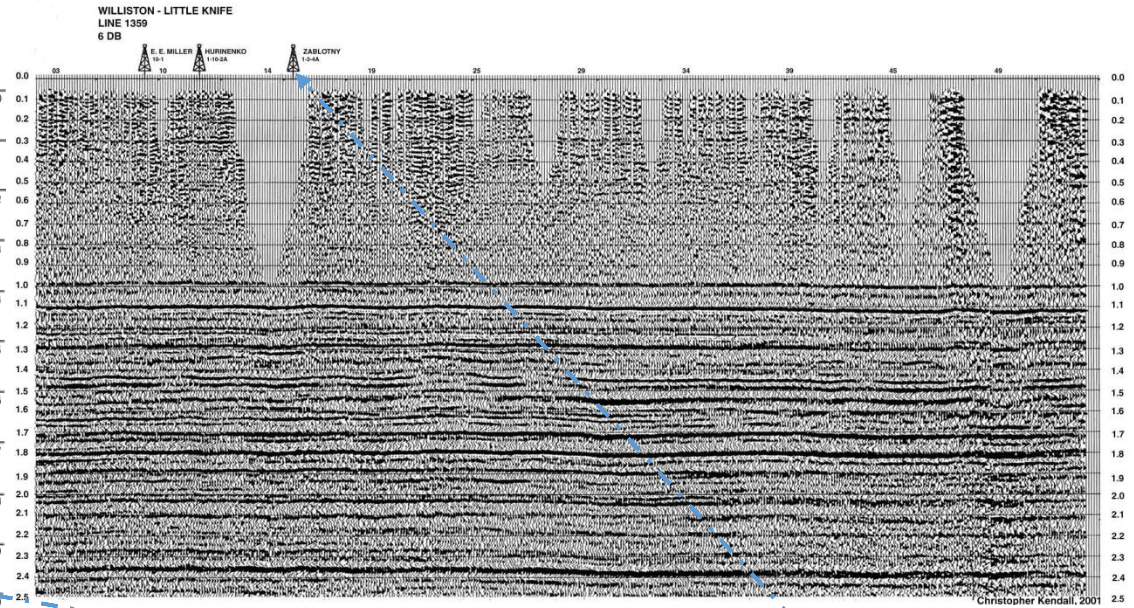
The **logs** plotted linearly over the time, at the same scale as the seismic section, can greatly help the **calibration** of the seismic profile.

Clearly this can be done when you also have **sonic log**.

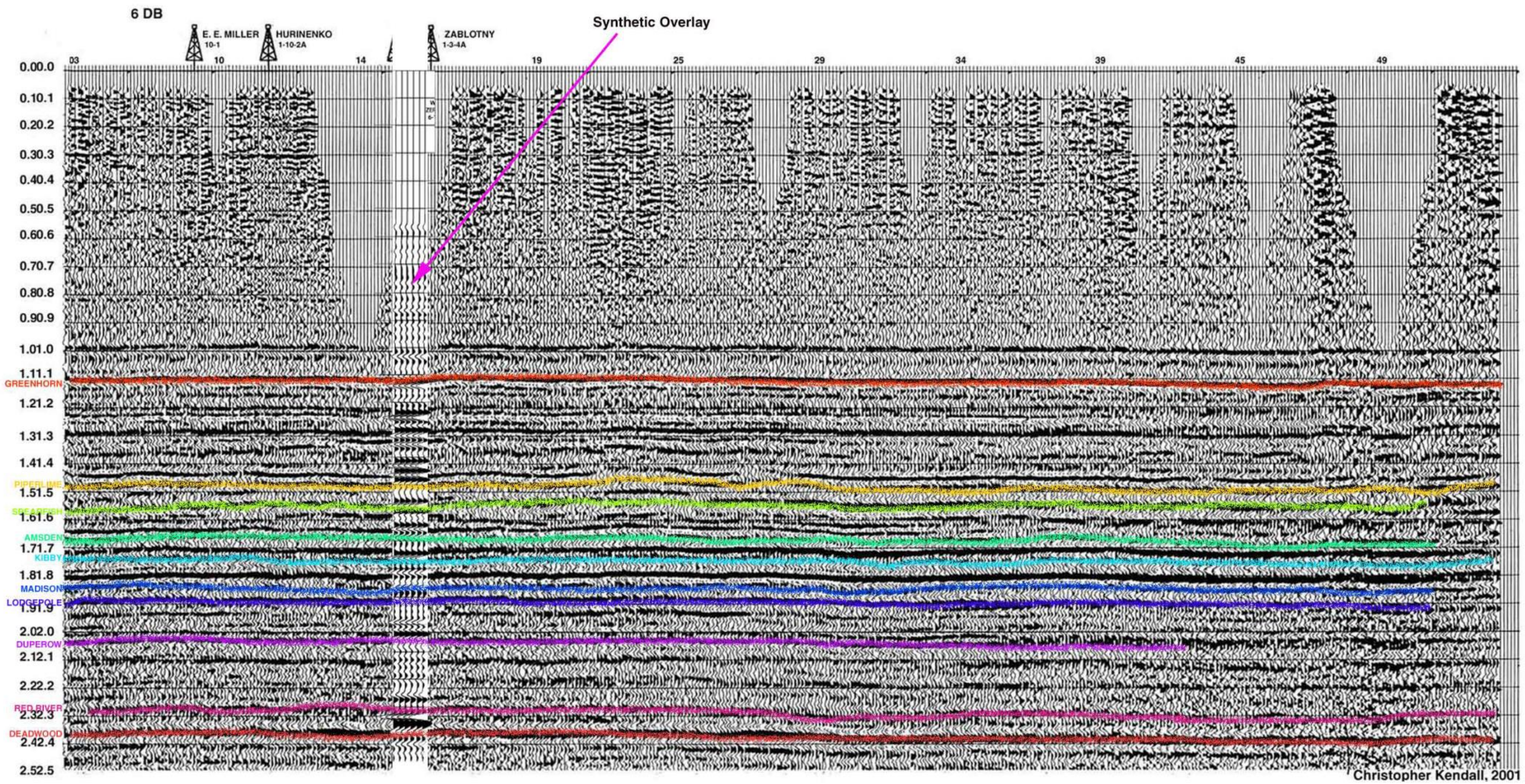
Vertical Seismic Profiles (VSP) are also useful in this regard.







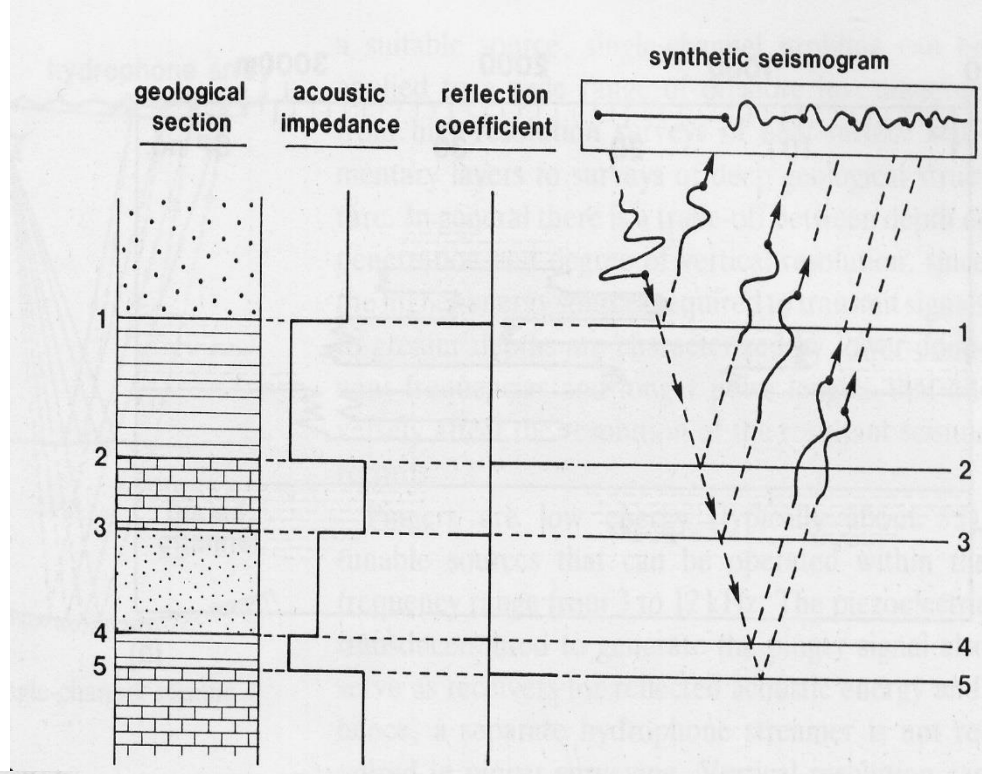
Example: a sonic log was acquired in a **well** (figure): this made it possible to calculate the **reflection coefficients** at different depths and, therefore, to build a **synthetic seismogram**. This seismogram, repeated 6 times, provides a brief **synthetic seismic section**, in which the seismic responses of the different lithological discontinuities, calibrated by the well, are highlighted. The synthetic section, at this point, is inserted and compared with the seismic profile at the well..

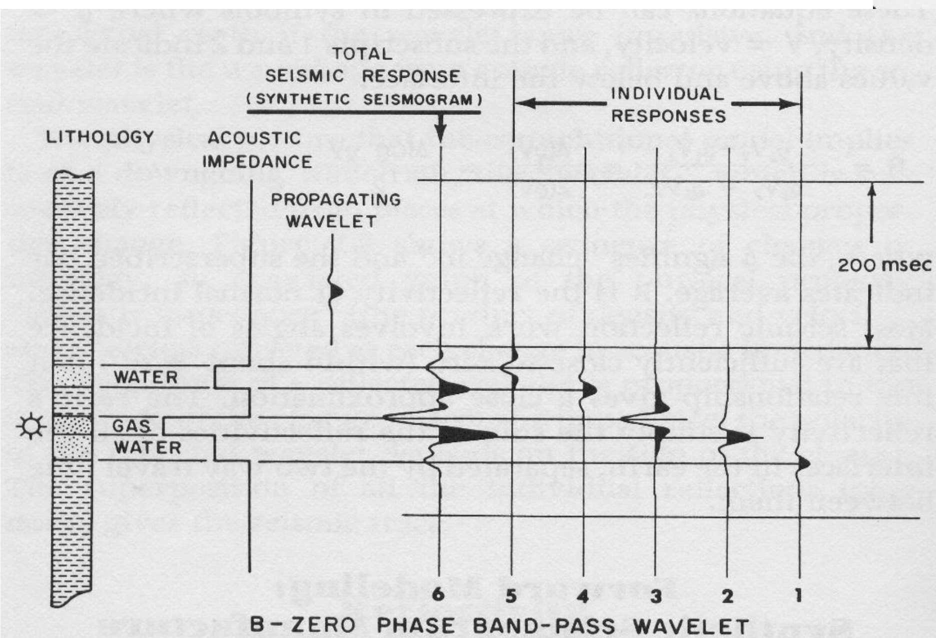


… the synthetic profile has been inserted in the acquired seismic profile, allowing to analyze the seismic characteristics of the single reflectors and to calibrate them with the geological and geophysical data of the well.

Use of synthetic seismograms and sections

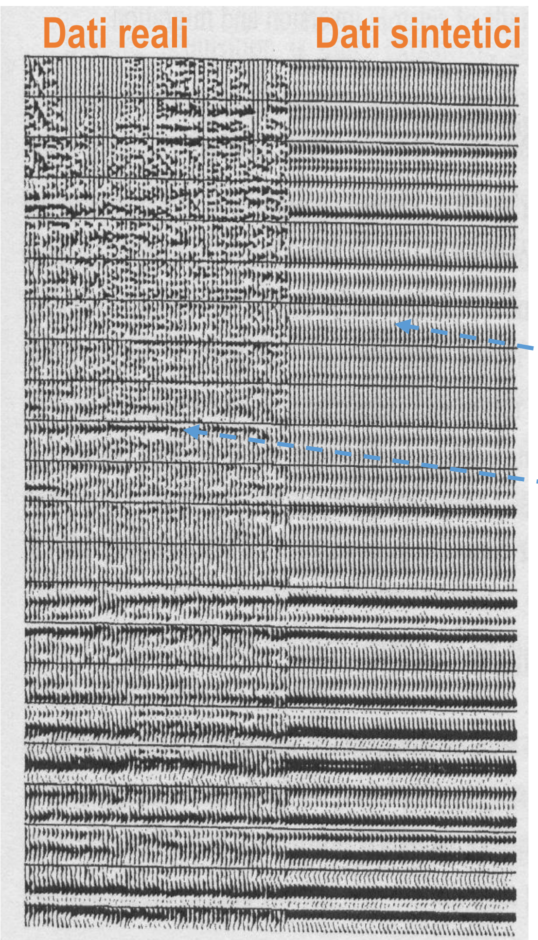
As we have seen, the construction of a synthetic seismogram or a synthetic section requires knowledge of velocities distribution as a function of depth.

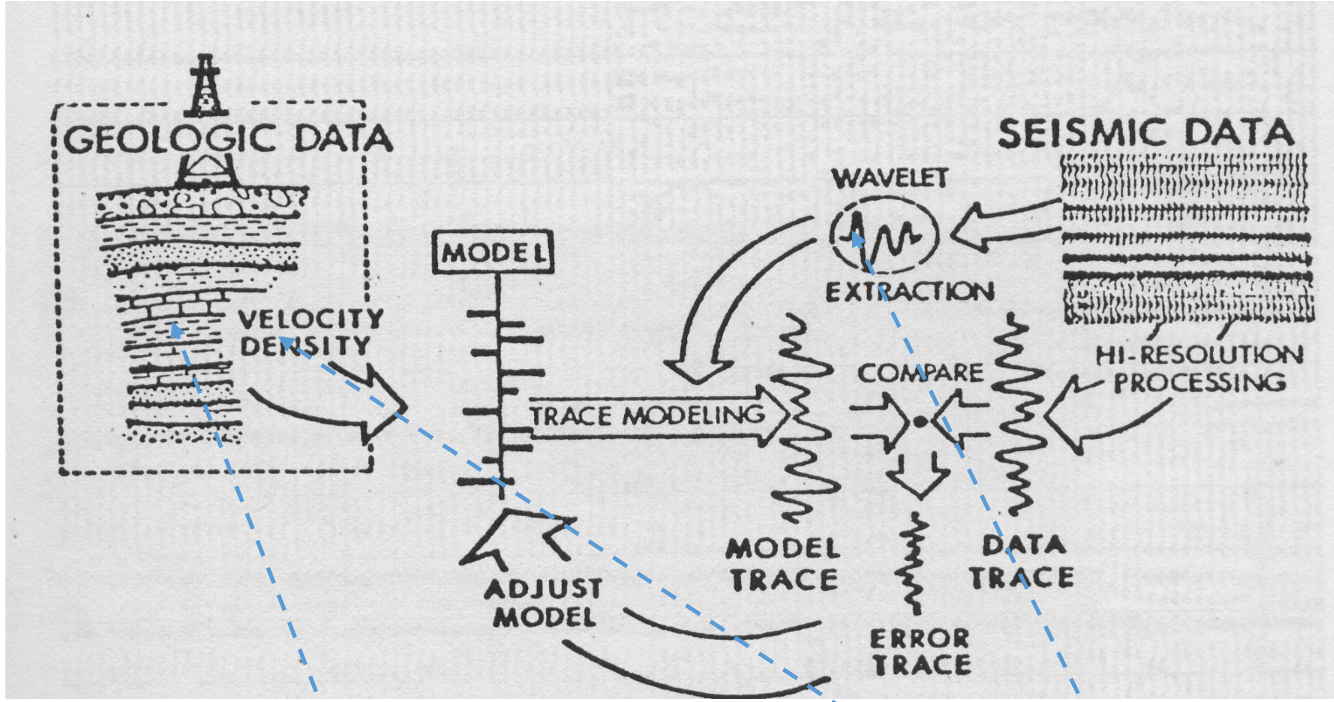




Reflection coefficients are often calculated by considering a constant density with depth. Alternatively, logs such as gamma-ray are used, if available, in order to use the exact acoustic impedance values.

Trace modeling





Trace modeling starts from a model of the distribution of sedimentary sequences with associated distribution of **density and velocity**.

The **reflectivity model** thus obtained is convolved with a **wavelet** (often deduced from the acquired seismic data).

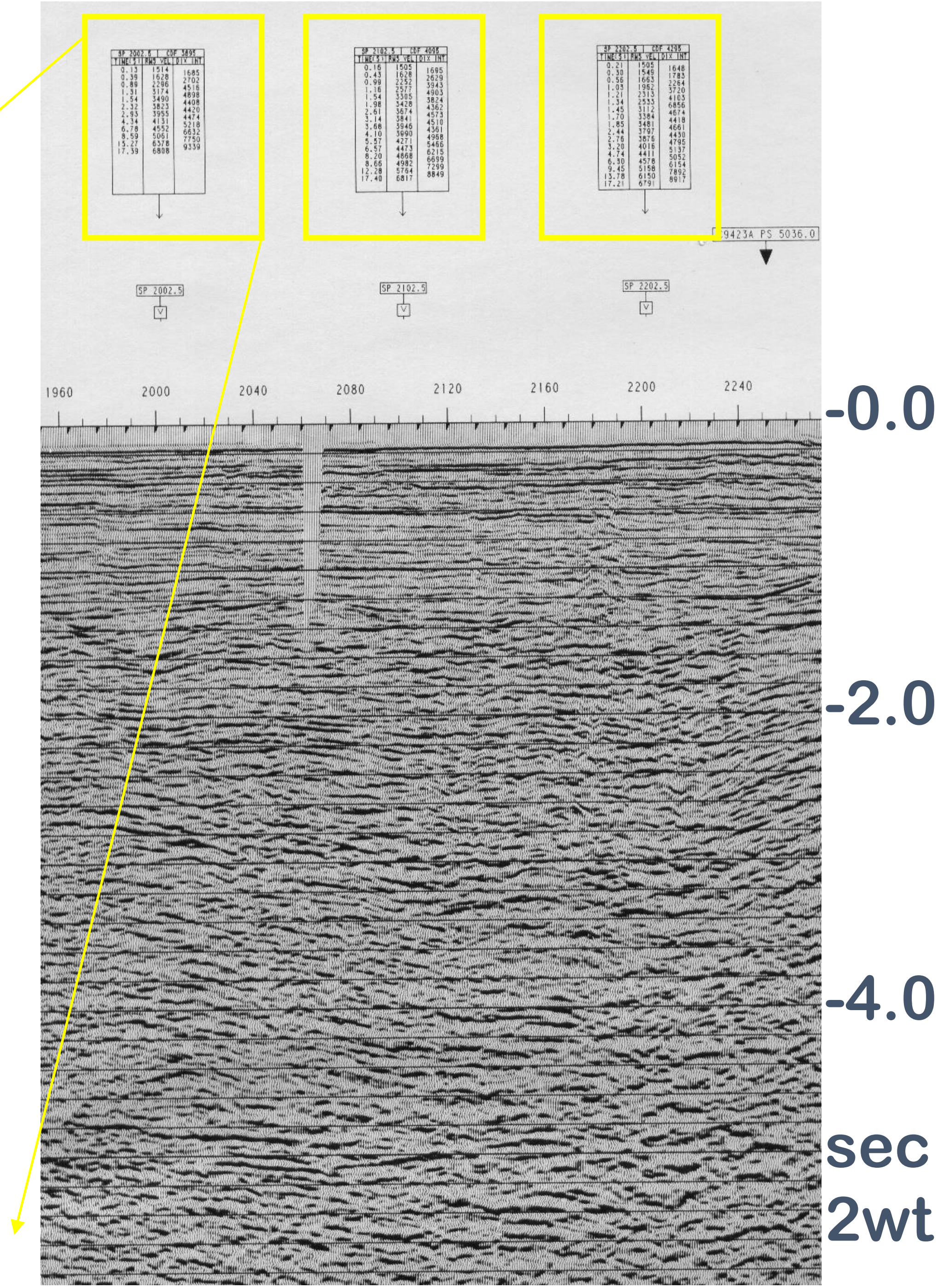
The result of the convolution will be a **synthetic section** that will be compared with **the recorded seismic section**.

The **differences** between the two sections will provide information on the variations that will be applied to the starting geological model, and this interactive procedure will be repeated until a synthetic profile sufficiently similar to the recorded profile is obtained.

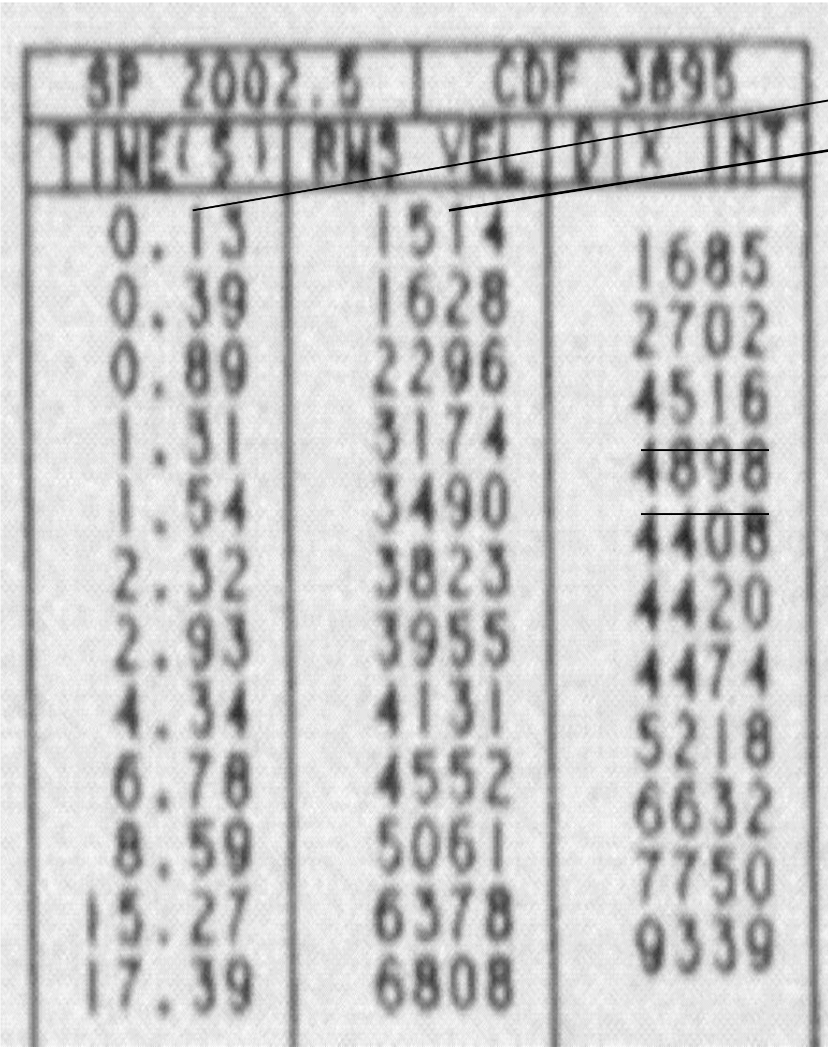
This similarity will support the accuracy of the geological model interpreted and adopted.

Often a stratigraphic well is available without knowing the distribution of velocities at depth. In this case, we use the speeds deduced from the analysis of the spectra, performed in the stacking phase of the CDPs and generally indicated along the seismic profiles.

SP 2002.5	CDP 3895	
TIME(S)	RMS VEL	DIX INT
0.13	1514	1685
0.39	1628	2702
0.89	2296	4516
1.31	3174	4898
1.54	3490	4408
2.32	3823	4420
2.93	3955	4474
4.34	4131	5218
6.78	4552	6632
8.59	5061	7750
15.27	6378	9339
17.39	6808	



Example



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15.27	6378	7750
17.39	6808	9339

(0,13sec/2)x1514 m/sec= 98,41 m

where:

- 0,13 sec is the 2wt depth of the sea bottom, that is 98,41 m
- 1514 m/sec water velocity

((0,39-0,13)sec/2)x1685 m/sec= 219,05 m

where:

-0,39 sec is the depth of the first reflector (below the sb) selected during the seismic processing

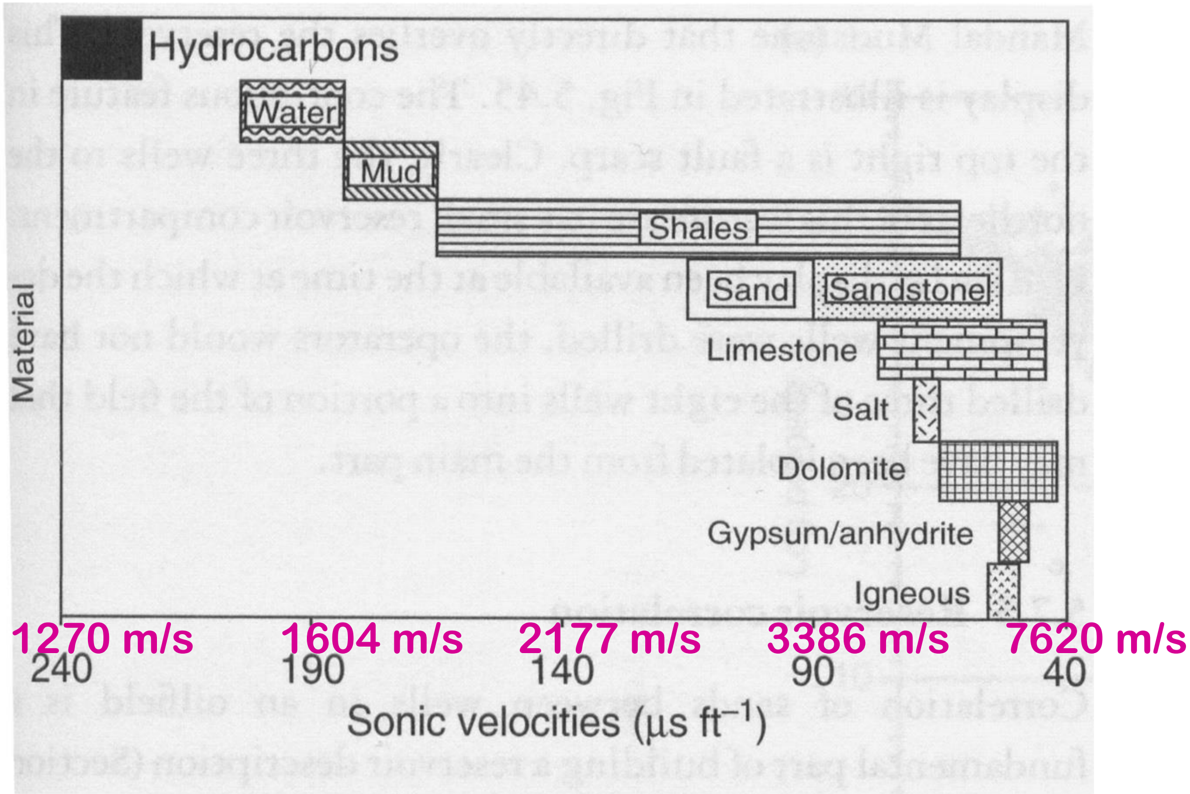
- 1685 m/sec is the velocity of the thickness between the sb and the reflector sited 0,39 sec.

=> 0,39 sec in 2wt depth corresponds to (98,41 + 219,05)m = 317,46 m

or:

(0,39 sec/2)x1628 m/sec = 317,46 m

and so on to deeper depths



P-wave velocities for various lithologies.

The interval velocity table can also be useful for lithological estimates.

The figure shows the velocity ranges of some typical lithologies: note that the unit of measurement on the abscissa is the microsec / foot, a typical unit of measurement in sonic logs, easily convertible into feet / sec or m / sec.

SP 2002.5	CDP 3895	
TIME(S)	RMS VEL	DIX INT
0.13	1514	
0.39	1628	1685
0.89	2296	2702
1.31	3174	4516
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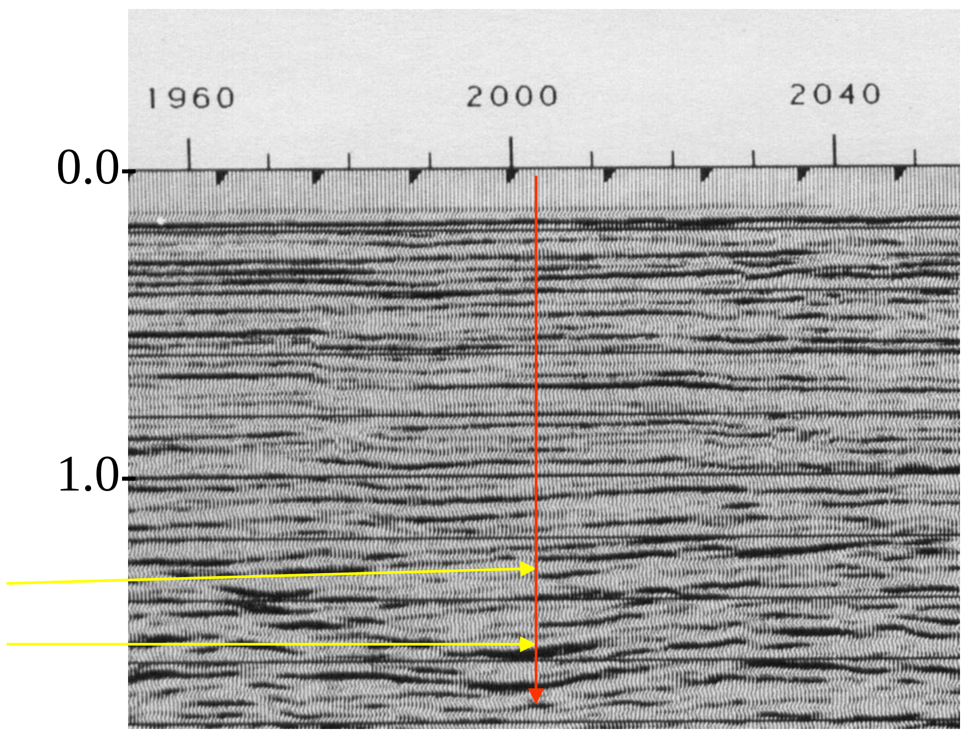
4.34	4131	4474
6.78	4552	5218
8.59	5061	6632
15.27	6378	7750
17.39	6808	9339

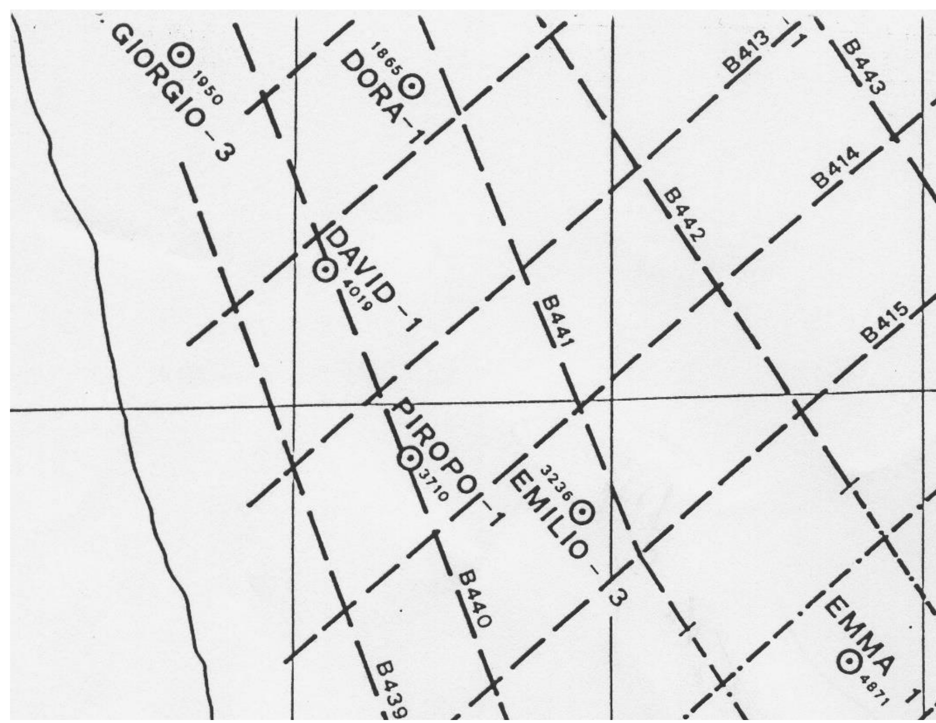
Example: in the interval velocity table, the thickness between 1.31 and 1.54 sec is characterized by high interval velocity, with inversion at the base from 4898 to 4408 m / sec: this suggests that it is the Messinian evaporite layer.



Thickness of the Messinian evaporite

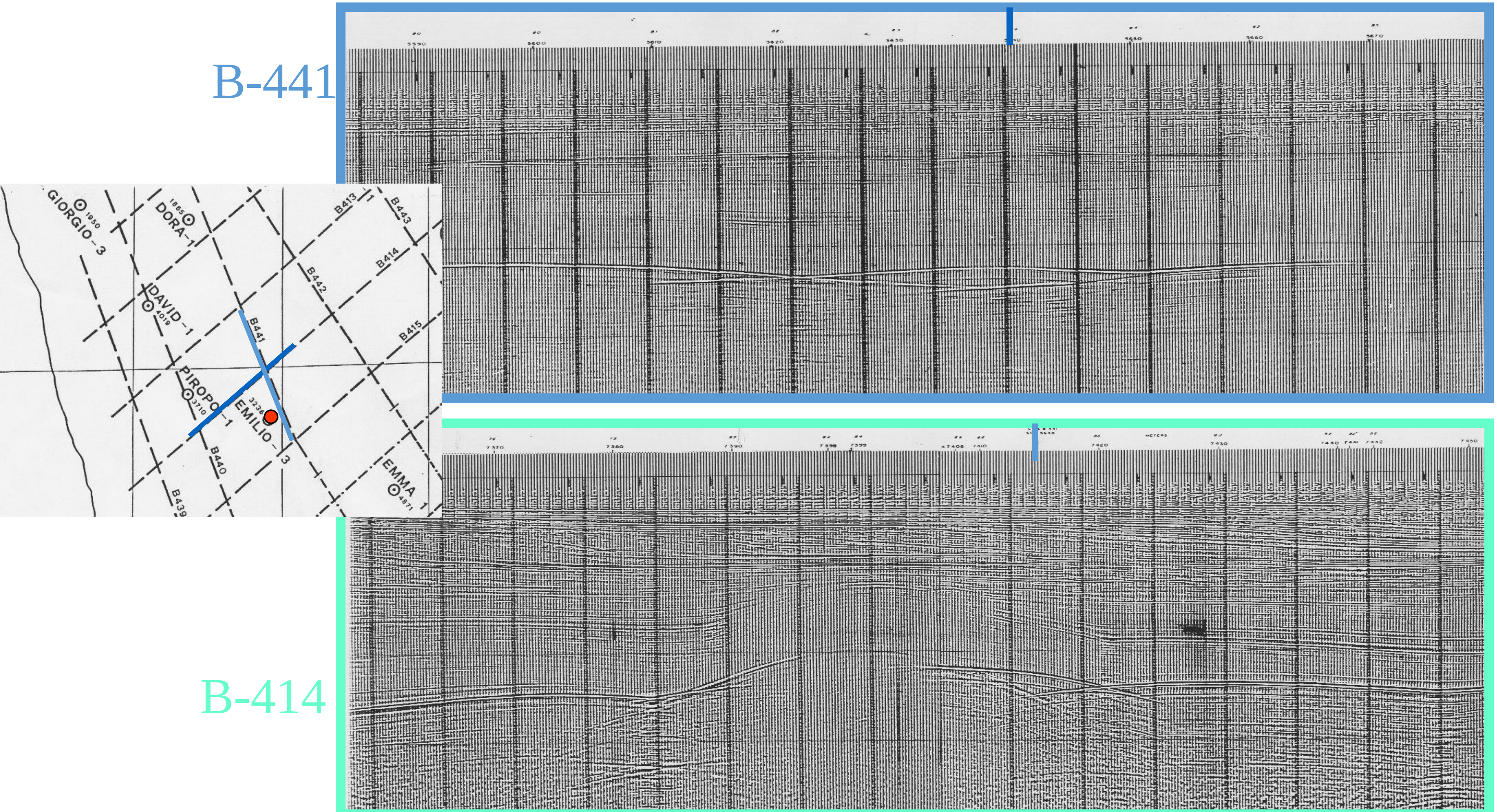
Often the well used for calibration is not exactly on one of the seismic profiles: it must therefore be projected. This procedure can be very delicate and problematic, especially if there are folded layers or intermediate faults. The projection of the well data already involves an interpretation, that is, the assumption of a hypothesis relating to both the progress of the strata and the effect of any faults present in the intermediate area between the well and the seismic profile.

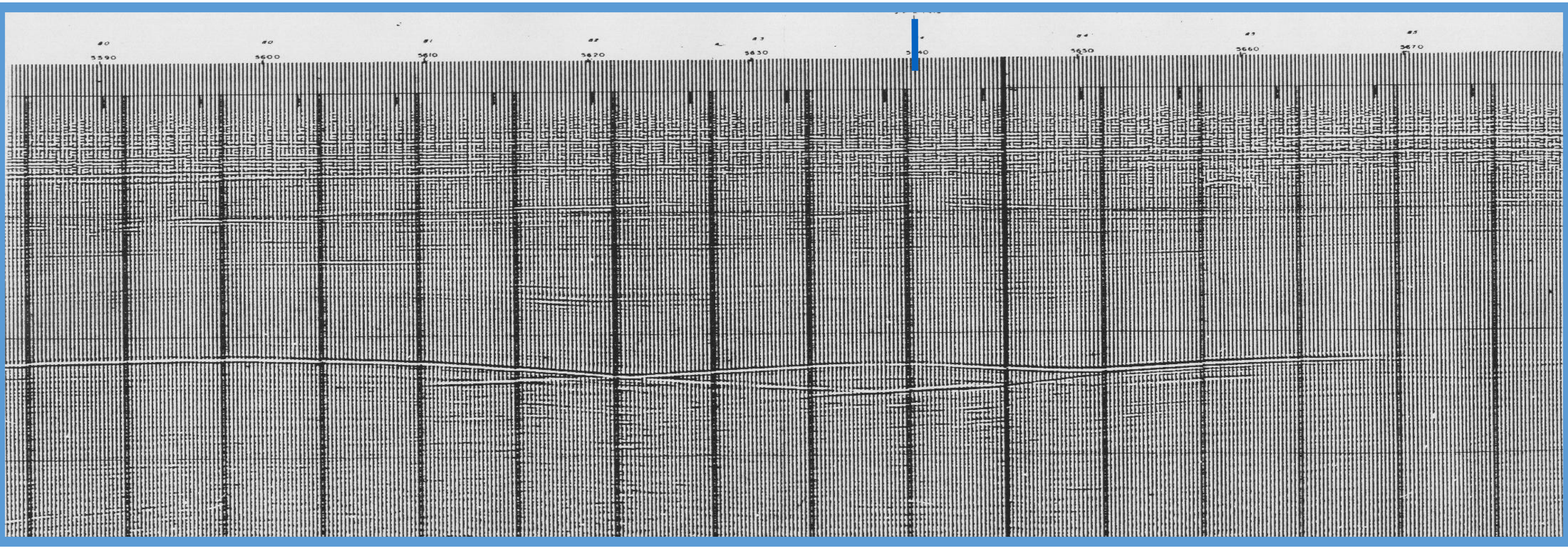
Therefore, it will first be necessary to establish any slopes of the layers along the profiles and subsequently to project the well data according to the structural axes.

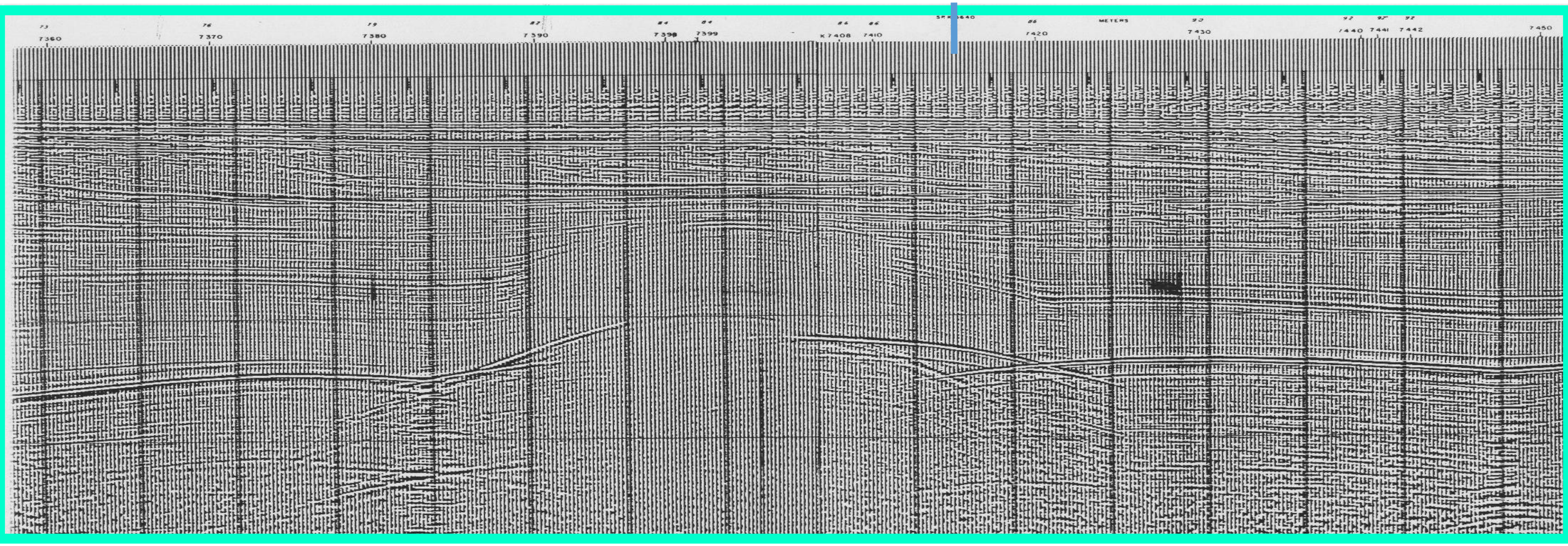


Example of seismic dataset and wells distribution in Adriatic

In the example in the figure, the Emilio-3 well shows a structure that is particularly evident along the seismic profile B-414, while there are only margin-structure reflectors along the profile B-441. This suggests that the structural trend will be roughly parallel to the B-441, and therefore the well data will have to be projected onto the B-414, although it is further away from the well itself.







The geometries of the most superficial layers, prograding from the west (coast line) to the east (center of the basin) are completely different (opposite slopes) compared to the deep reflectors.
Data coming from the same well, but different consideration at different depths.