

Reflection Seismic Processing

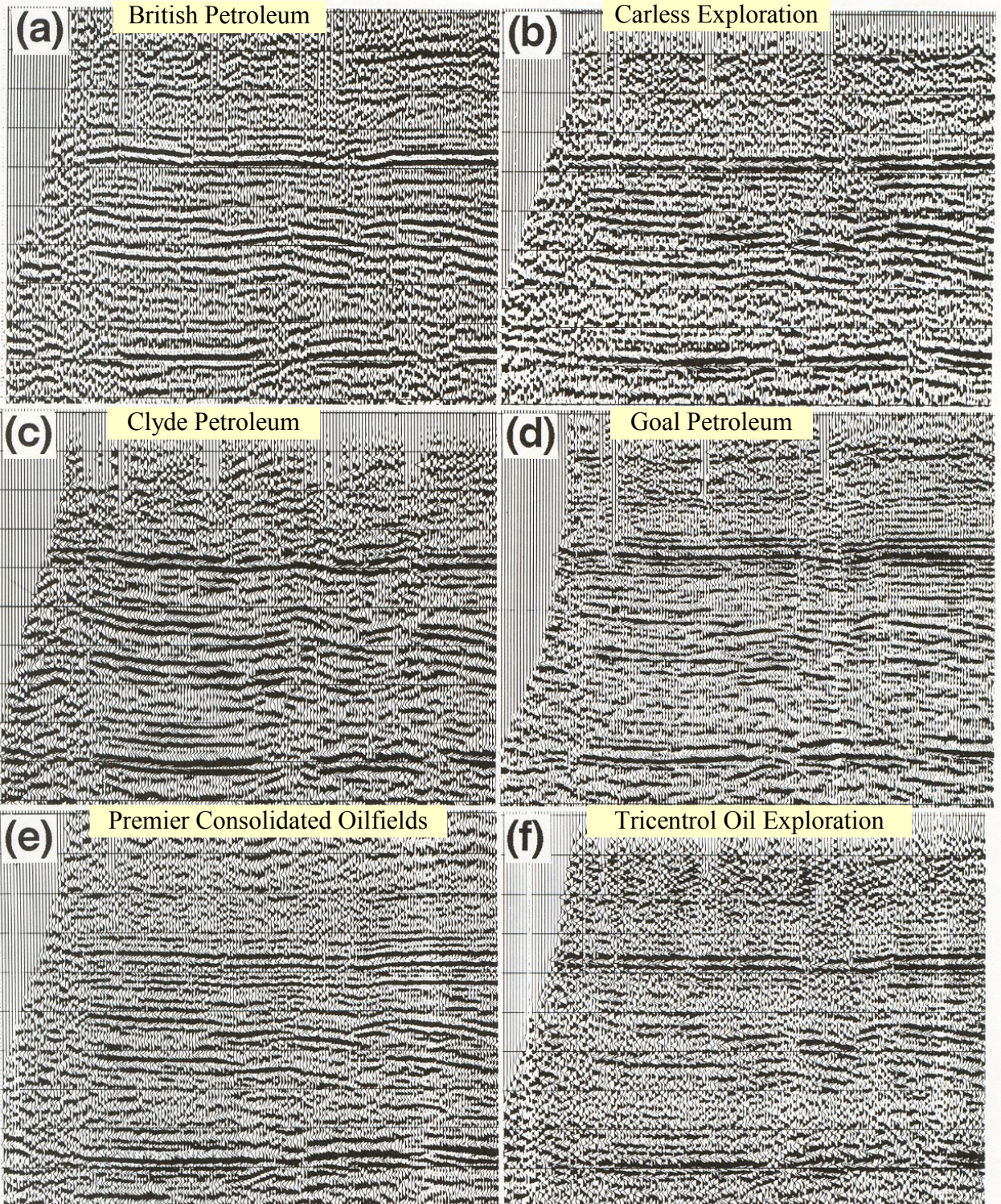
- General CMP processing sequence
- Highlights of some key steps
- Reading:
 - › Sheriff and Geldart, Chapter 9

Reflection Seismic Processing

- Objective - transform redundant reflection seismic records in the *time domain* into an interpretable *depth image*.
 - Data reduction and editing;
 - ◆ Transformation into conveniently computer-manageable form;
 - ◆ Removal of bad records;
 - Gathering;
 - ◆ CMP sorting;
 - Filtering in time and space;
 - ◆ Attenuation of noise;
 - Imaging
 - ◆ Final velocity and reflectivity image.

Importance of processing

A line processed by several contractors



Seismic Processing Systems

- Usually geared to a particular type of application
 - ◆ Mostly CMP reflection processing;
 - ◆ Land or marine, 2D or 3D.
- Commercial:
 - ◆ ProMAX (Landmark);
 - ◆ Omega (Western Geophysical, marine);
 - ◆ Focus (Paradigm);
 - ◆ Amoco and almost every other company have their own...
 - ◆ Vista (Seismic Image Soft.).
- Universities:
 - ◆ Stanford Exploration Project;
 - ◆ Seismic UNIX (Colorado School of Mines);
 - ◆ FreeUSP (Amoco);
 - ◆ SIOSEIS (Scripps, marine);
 - ◆ Our very own

CMP Processing Sequence

- 1) Demultiplex, Vibroseis correlation, Gain recovery
 - ◆ Conversion from file formats produced by field data loggers into processing-oriented formats
 - SEG-Y, SEG-2.
 - ProMax, Focus, Omega, SU, Vista, etc., internal formats.
 - ◆ Often done in the field.
- 2) Field Geometry
 - ◆ Assignment of source-receiver coordinates, offsets, etc. in the *trace headers*.
- 3) Edit
 - ◆ Removal of bad traces (noisy channels, poorly planted geophones, channels contaminated by power line noise, etc.).

CMP Processing sequence (continued)

- 4) First arrival picking
 - ◆ May be semi-automatic or manual;
 - ◆ Required for generation of *refraction statics*; models and for designing the *mutes*.
- 5) Elevation statics
 - ◆ Based on geometry information, compensates the travel-time variations caused by variations in source/receiver elevations.
 - ◆ Transforms the records as if recorded at a common horizontal *datum* surface.
- 6) Refraction statics
 - ◆ Builds a model for the shallow, low-velocity subsurface;
 - ◆ Compensates travel-time variations caused by the shallow velocities.
- 7) 'Top', 'bottom', and 'surgical' *mute*
 - ◆ Eliminates (sets amplitude=0) the time intervals where strong non-reflection energy is present:
 - ◆ First arrivals, ground roll, airwave.

CMP Processing Sequence (continued)

8) Gain recovery

- ◆ Compensates geometrical spreading;
- ◆ Based on a simple heuristic relation.

9) Trace balance

- ◆ Equalizes the variations in amplitudes caused by differences in *coupling*;
- ◆ In true-amplitude processing, replaced with '*surface-consistent deconvolution*'.

10) Deconvolution or wavelet processing

- ◆ Compresses the wavelet in time, attenuates reverberations.
- ◆ Converts the wavelet to zero-phase for viewing

11) Gather, CMP sort

- ◆ Often (in ProMax, Omega, Vista) done by using *trace lookup* tables instead of creating additional copies of the dataset.

12) Moveout (Radon, τ - p , f - k) filtering

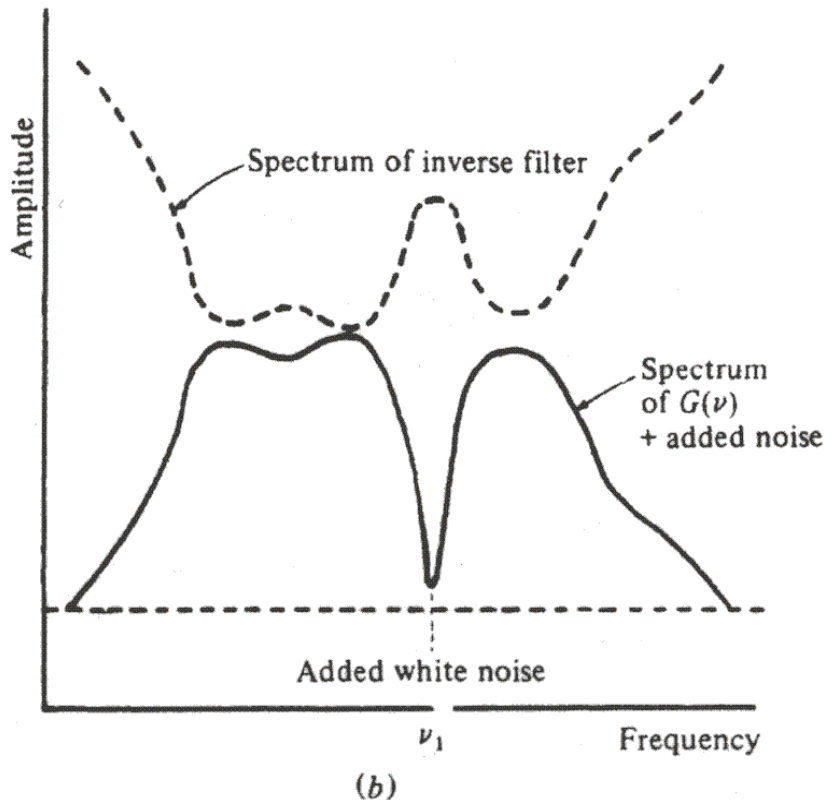
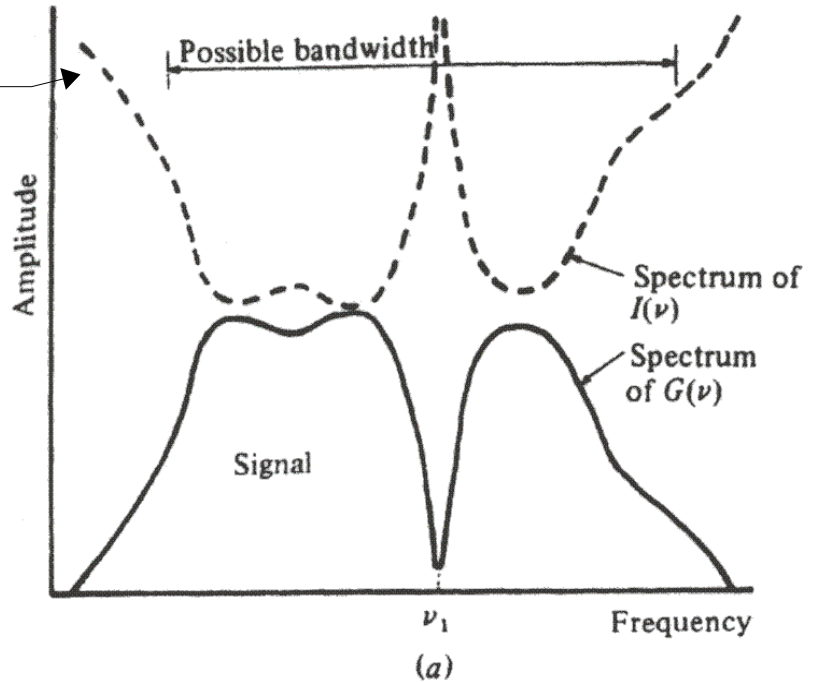
- ◆ Attenuates multiples, ground roll.

Deconvolution

Deconvolving (inverse) Filter

Objectives:

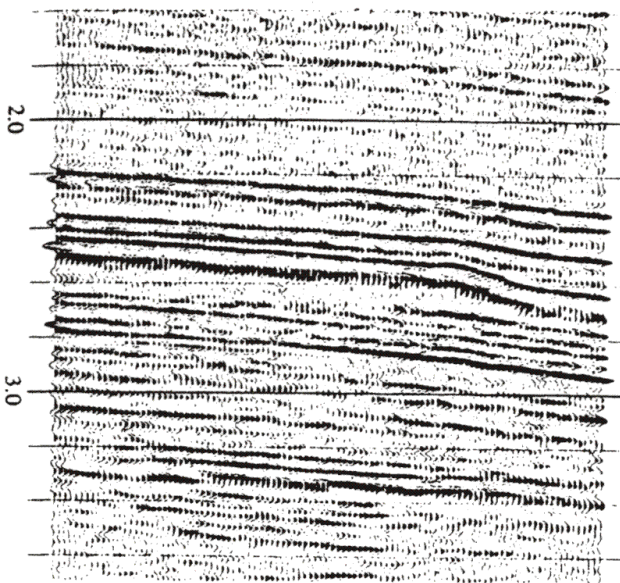
- 1) Compress the wavelet into a sharp minimum- or zero-phase shape;
- 2) Remove predictable (short-period multiple) part of the signal;
- 3) Broaden (flatten) the spectrum.



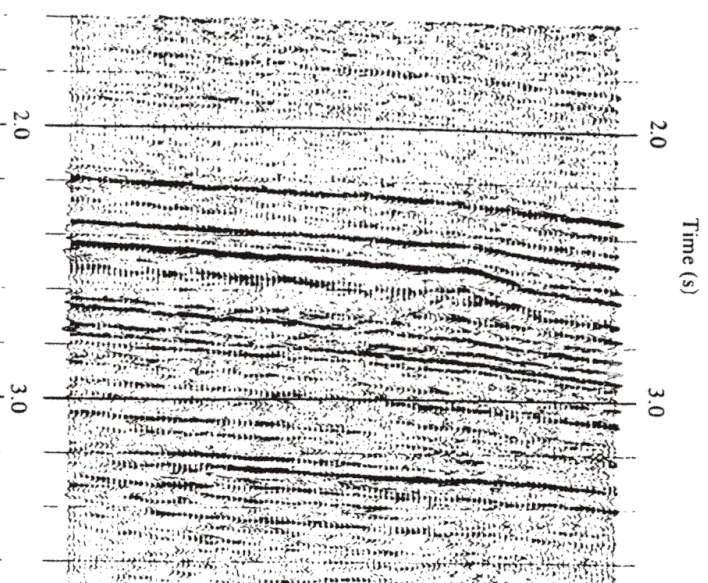
More on deconvolution in *Filtering* section later...

Wavelet shaping

- Shape of the source wavelet is estimated from autocorrelation of the data
- Time-variant “spectral whitening” (flattening within an estimated bandwidth) is applied
- A filter is designed to convert the wavelet into zero-phase



Migrated stack before
wavelet processing



Migrated stack after
wavelet processing

CMP Processing Sequence (continued)

13) Velocity analysis

- ◆ For each of the CMP gathers, determines the optimal *stacking velocity*.

14) Dip Moveout (DMO) correction

- ◆ Transforms the records so that the subsequent NMO+stack work well even in the presence of dipping reflectors.

15) Normal Moveout (NMO) correction

- ◆ Removes the effects of source-receiver separation from reflection records;
- ◆ Transforms the records as if recorded at normal incidence.

16) Residual statics

- ◆ Removes the remaining small travel-time variations caused by inaccurate statics or velocity model

Normal Moveout (NMO) correction

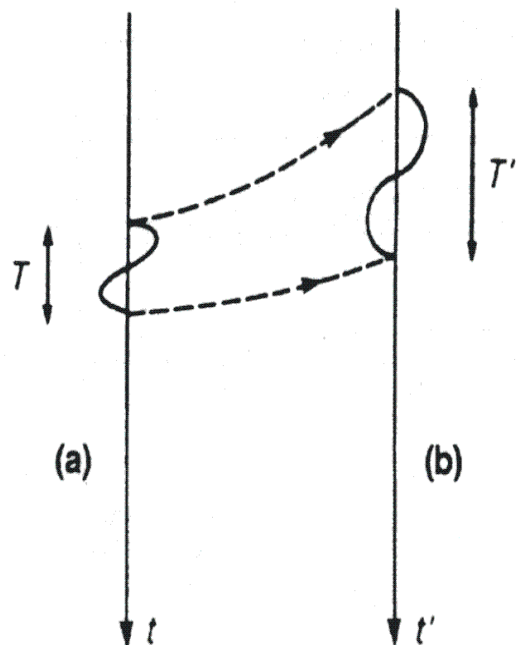
- NMO correction transforms a reflection record at offset x into a normal-incidence ($x=0$) record:

$$t_0 = \sqrt{t^2(x) - \left(\frac{x}{V}\right)^2} \approx t(x) - \frac{1}{2t(x)} \left(\frac{x}{V}\right)^2$$

“Stacking velocity”

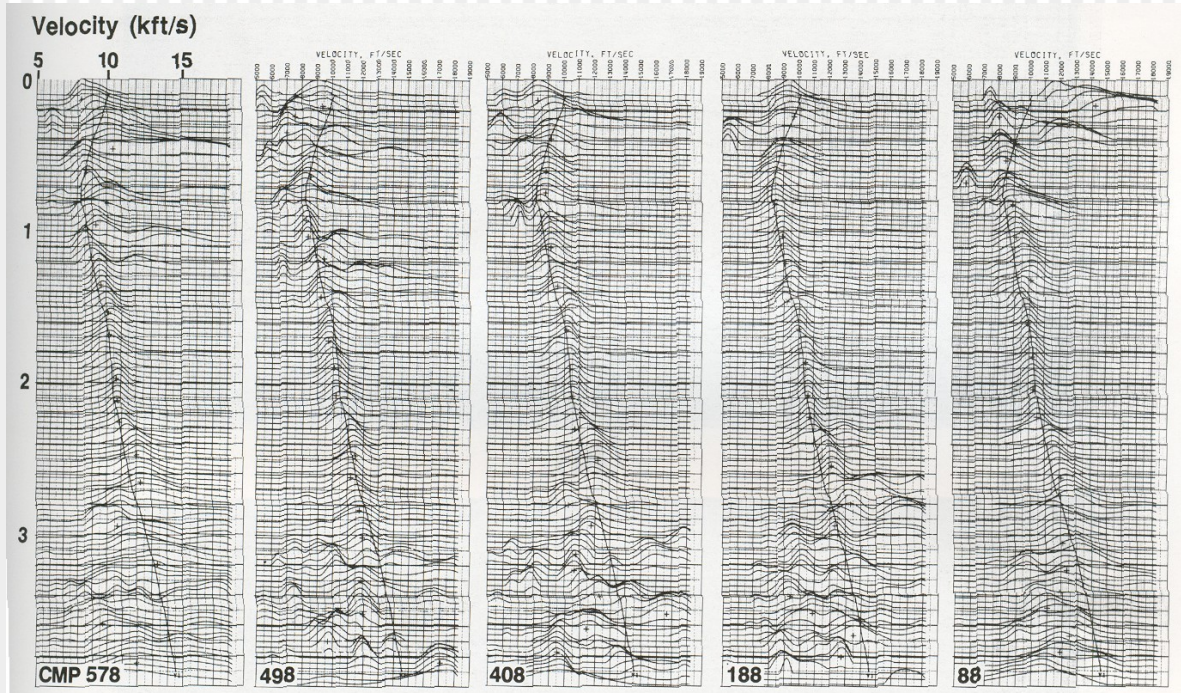
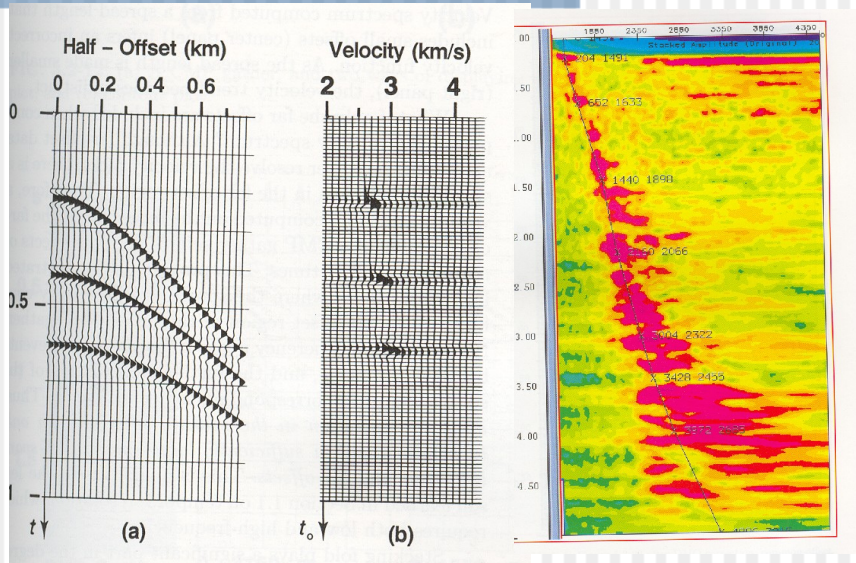
NMO correction

- NMO correction stretches shallower and slower reflections stronger
 - This affects the spectrum of the stack
 - This distortion is controlled during processing by setting a limit in relative stretch (typically $\sim 25\%$)



Velocity Analysis

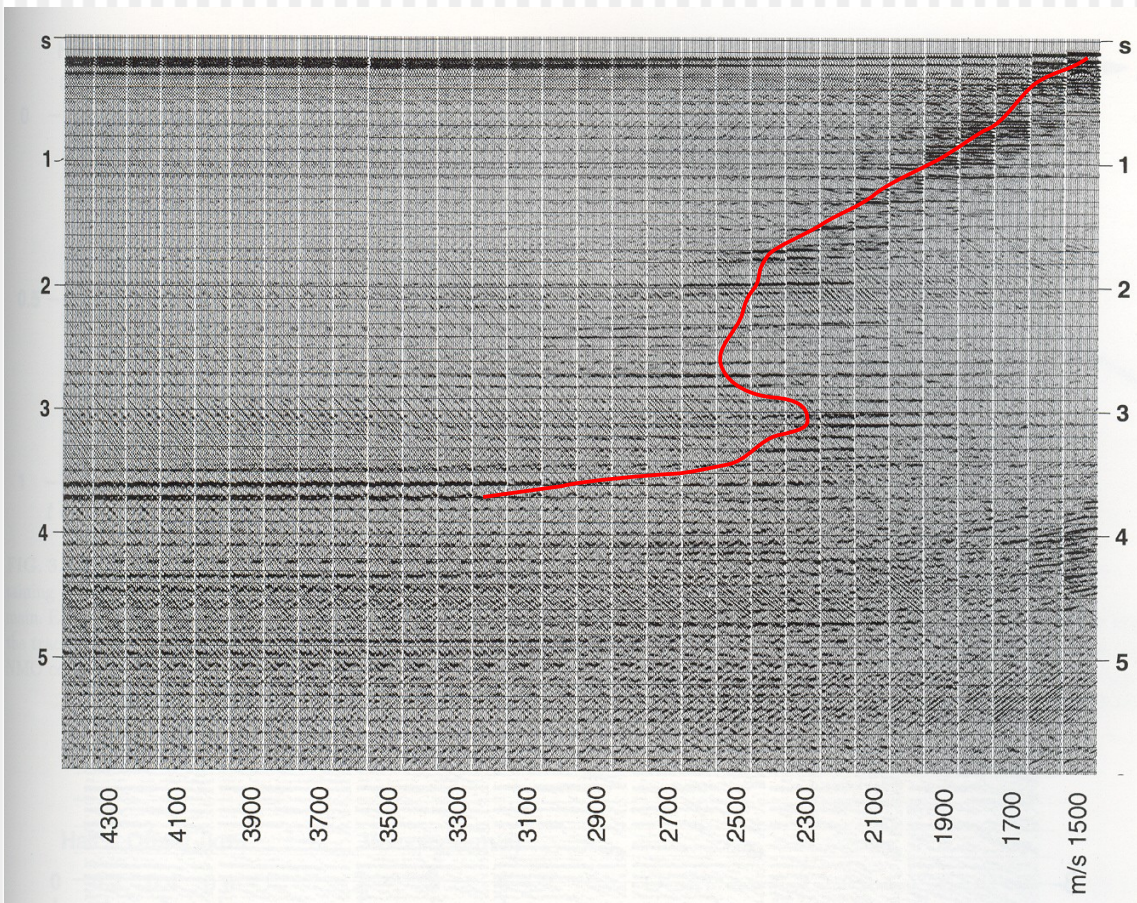
CMP gathers are stacked along trial-velocity hyperbolas and presented in time-velocity diagrams.



Velocity analysis

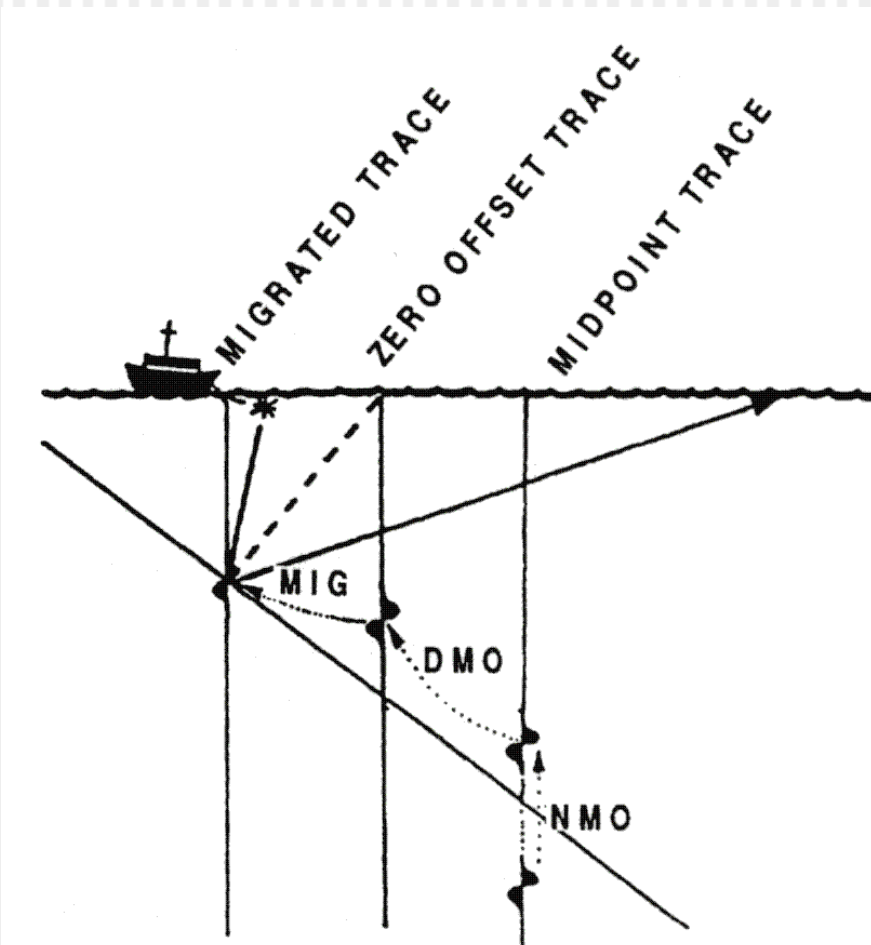
(Common-Velocity Stacks)

- Groups of CMP gathers are NMO-corrected (hyperbolas flattened) using a range of trial velocities and stacked.
- Velocities are picked at the amplitude peaks and best resolution in the stacks.



NMO → DMO → Migration

- DMO assists NMO by correcting for the time delay on an offset trace assuming zero dip.
- For a dipping reflector, DMO moves the data to the correct zero-offset trace. Migration further moves it to the subsurface location.

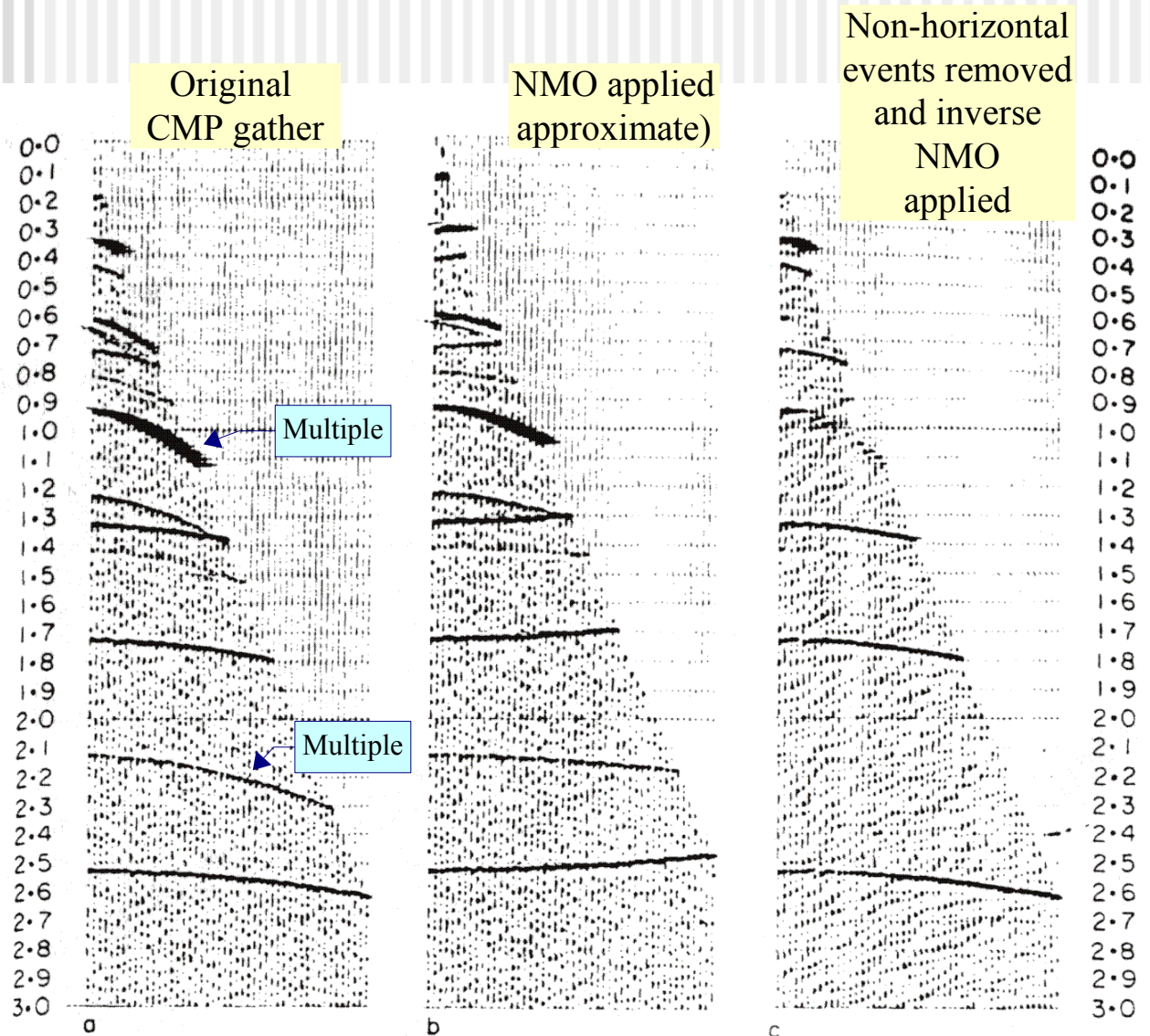


CMP Processing Sequence (continued)

- 17) Steps 13-16 above are usually iterated 3-5 times to produce accurate *velocity* and *residual statics* models.
 - ◆ Success of velocity analysis depends on the quality of DMO/NMO and residual statics, and vice versa.
- 18) CMP Stack
 - ◆ Produces a *zero-offset section*;
 - ◆ Utilizes CMP redundancy to increase the *Signal/Noise ratio*.
 - ◆ Can employ various normalization ideas, e.g., *diversity stack*
- 19) Migration
 - ◆ Transforms the zero-offset *time* section into a depth image;
 - ◆ Establishes correct extents and dips of the reflectors.
- 20) Frequency filtering and display
 - ◆ Attenuates noise
 - ◆ Provides best display for interpretation

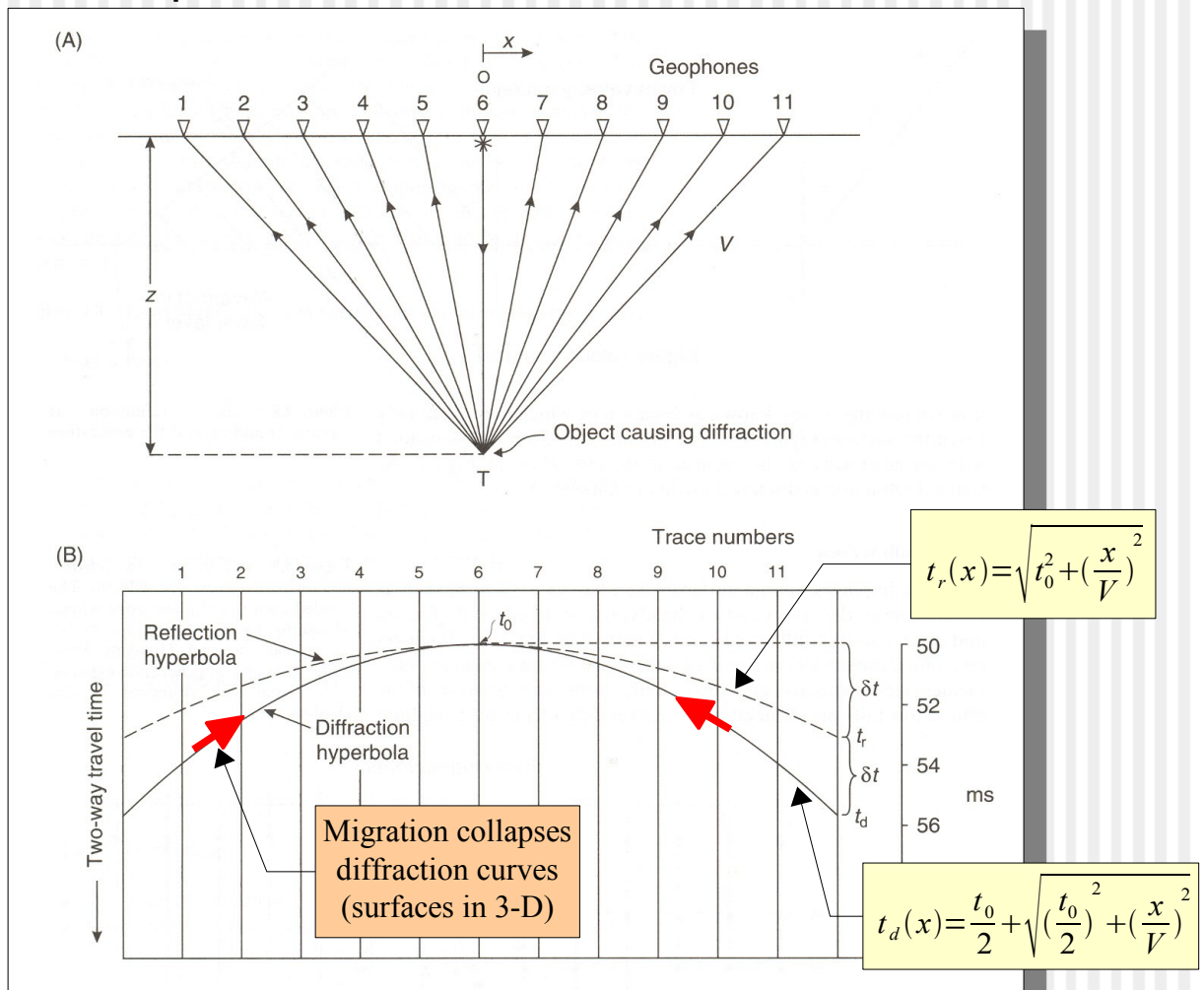
Moveout ($f-k$, $\tau-p$) filtering

- Removes coherent events with undesired moveouts

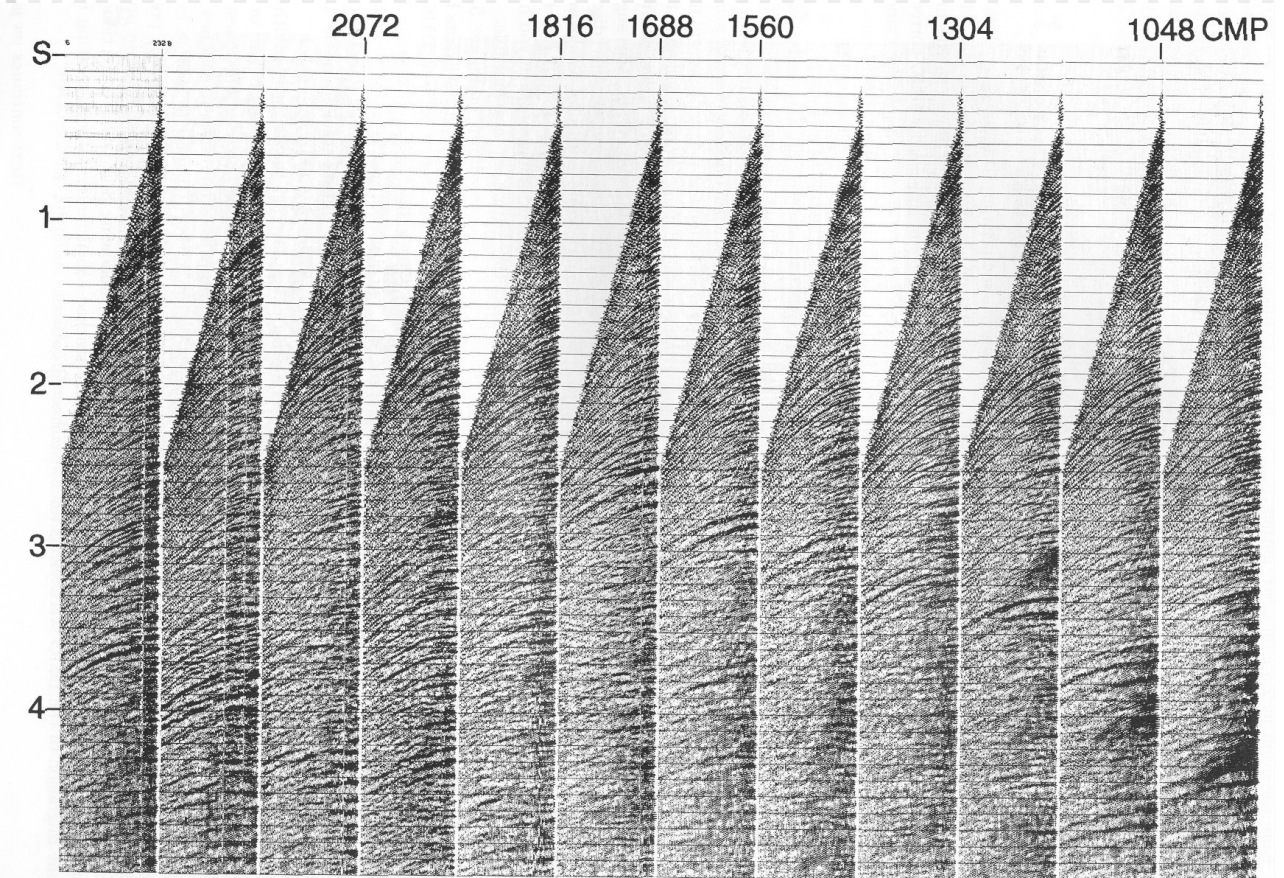


Migration

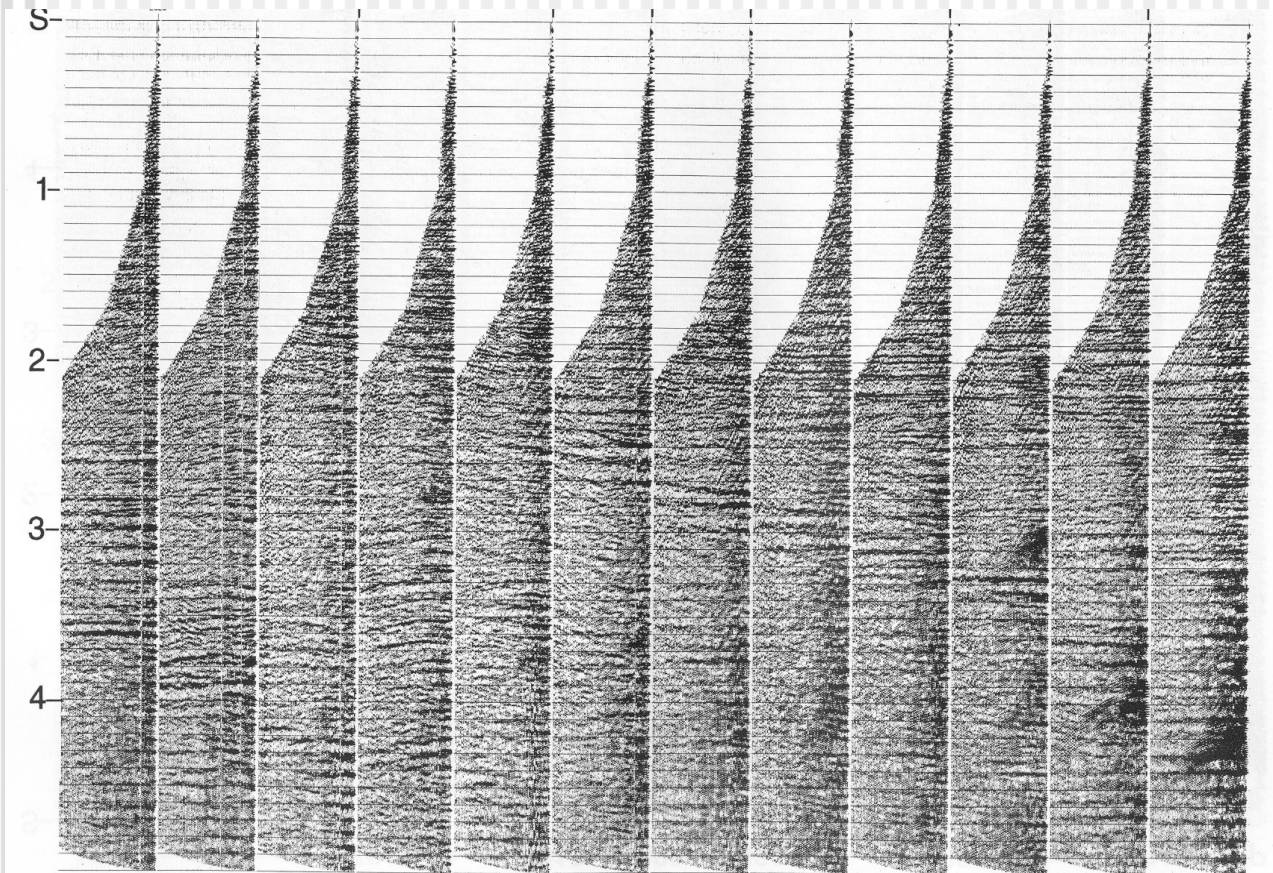
- A simplified variant of '*inversion*'
 - ◆ Inverts 'time section' for true 'depth image'.
- Establishes true positions and dips of reflectors.
- Collapses diffractions.



Example: CMP gathers

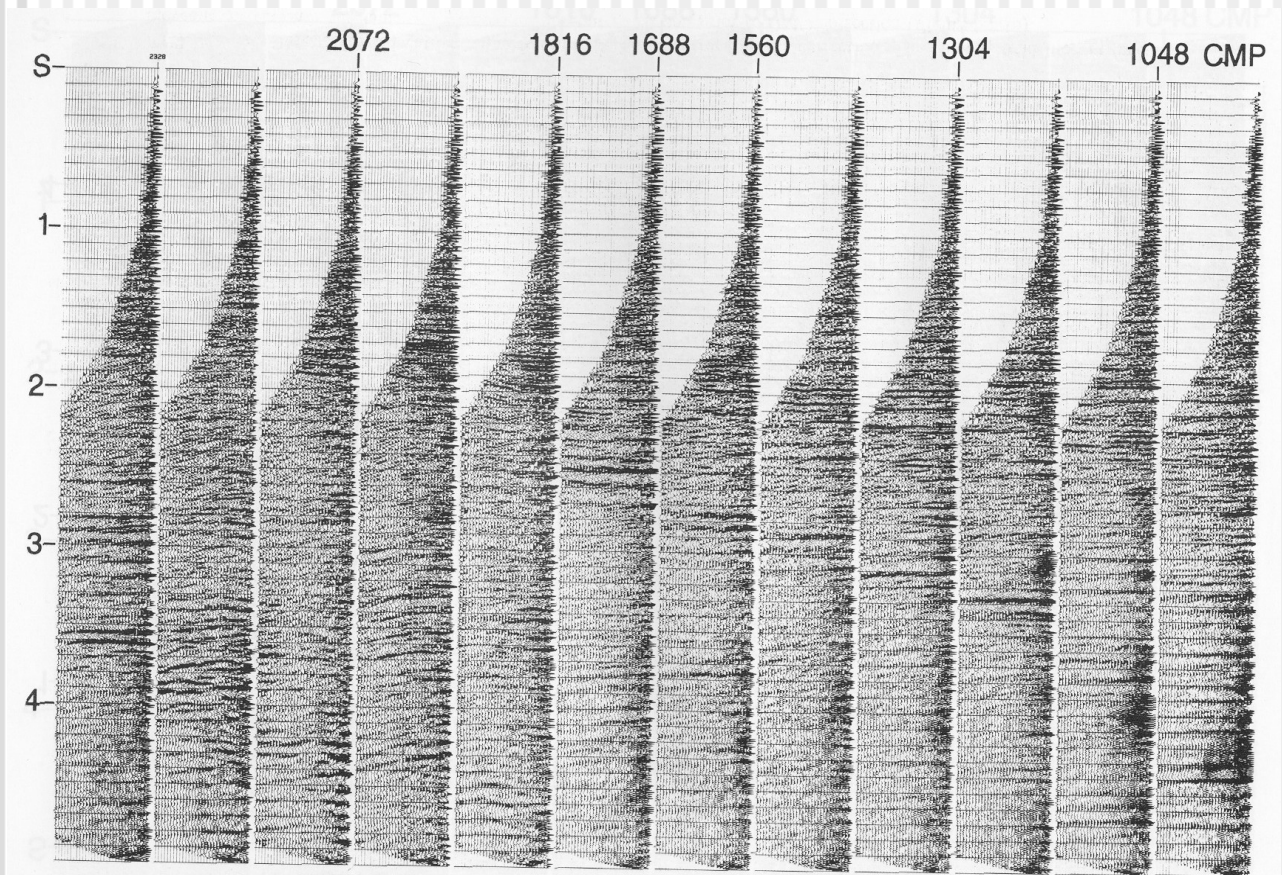


Example: CMP gathers after NMO correction

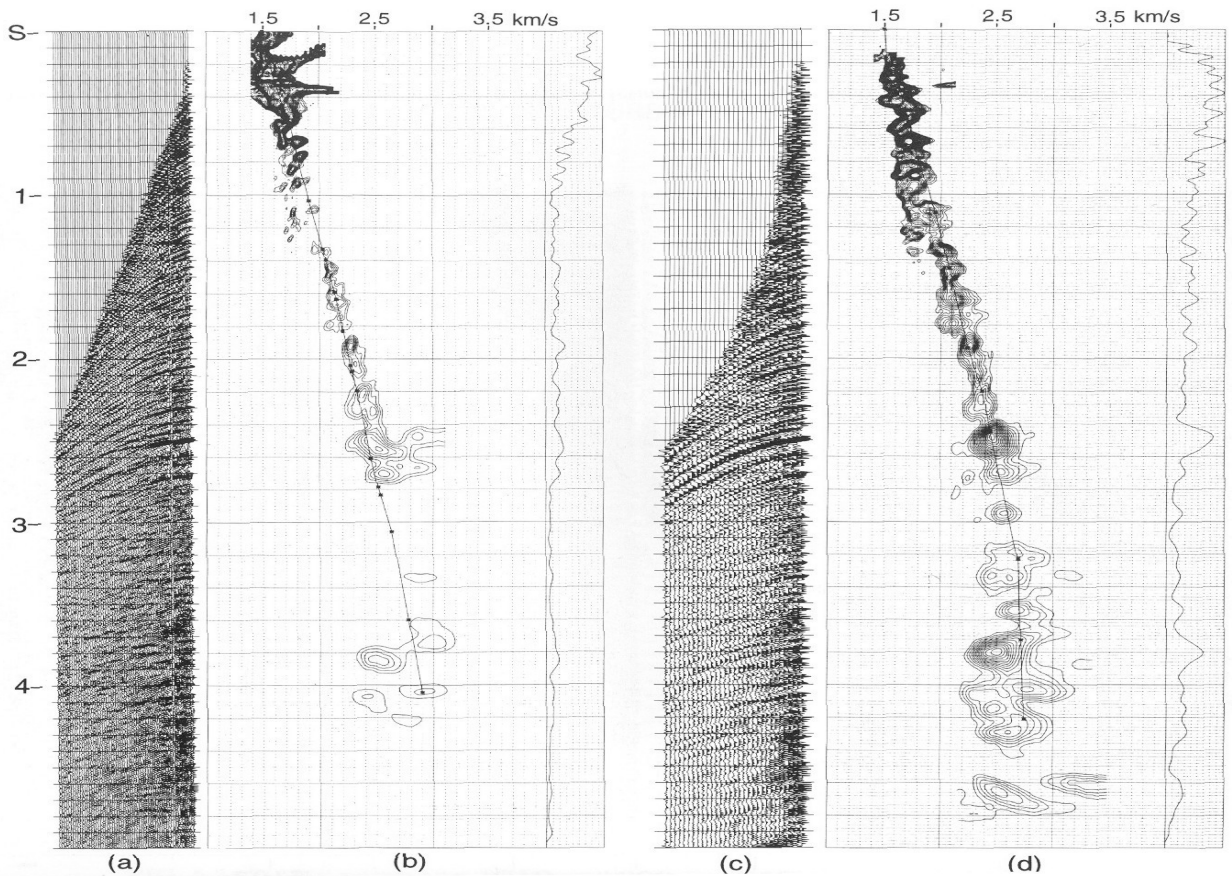


Example:

CMP gathers after NMO+DMO corrections



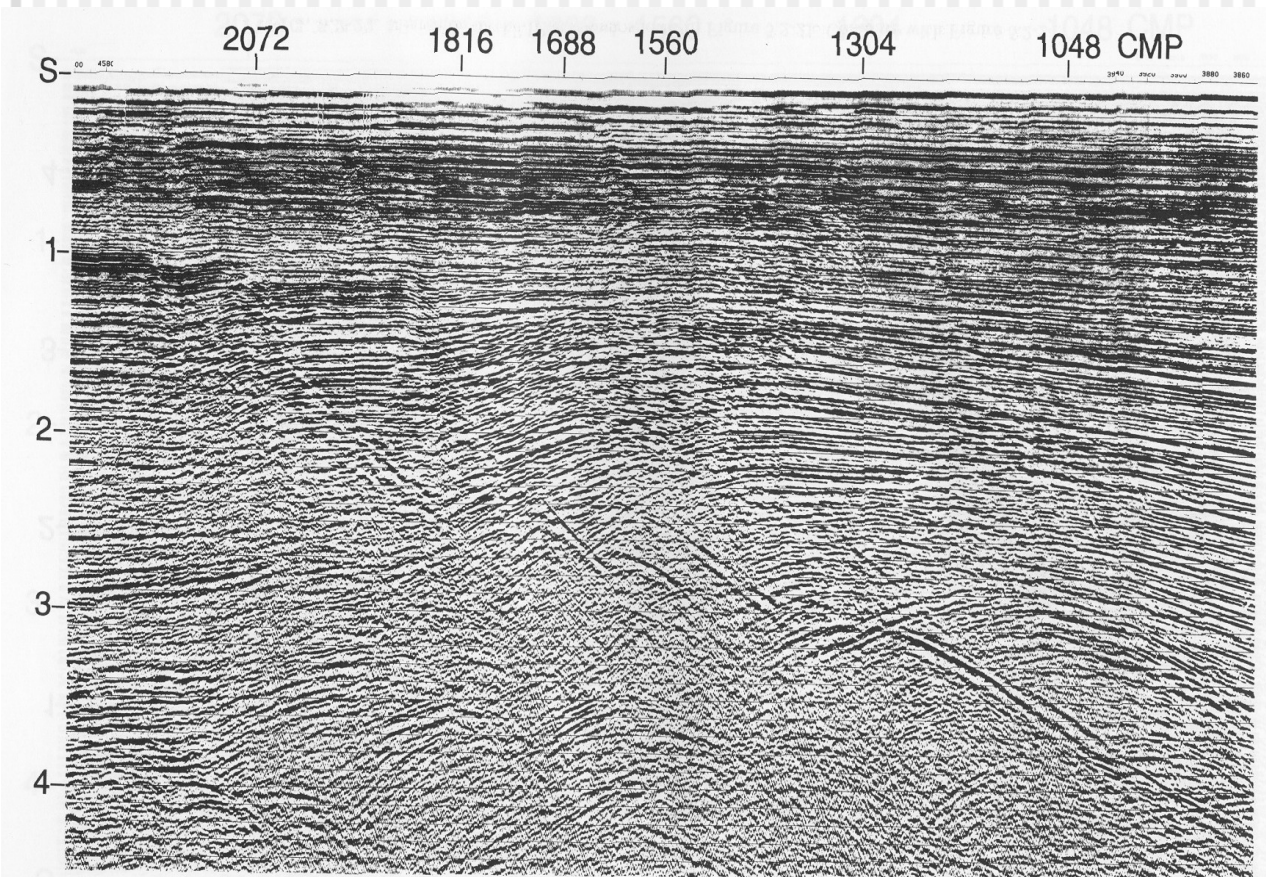
Example: Velocity analysis



Without DMO

With DMO

Example: NMO(with DMO) stack *Zero-offset section*



Example: Final migrated stack

