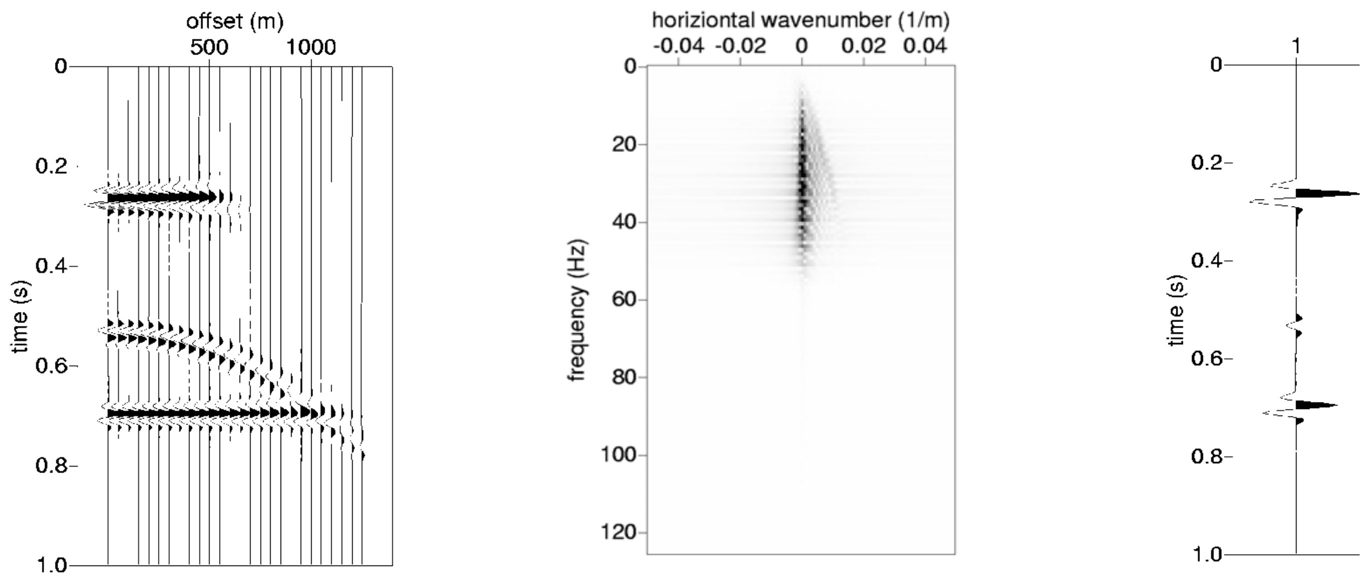
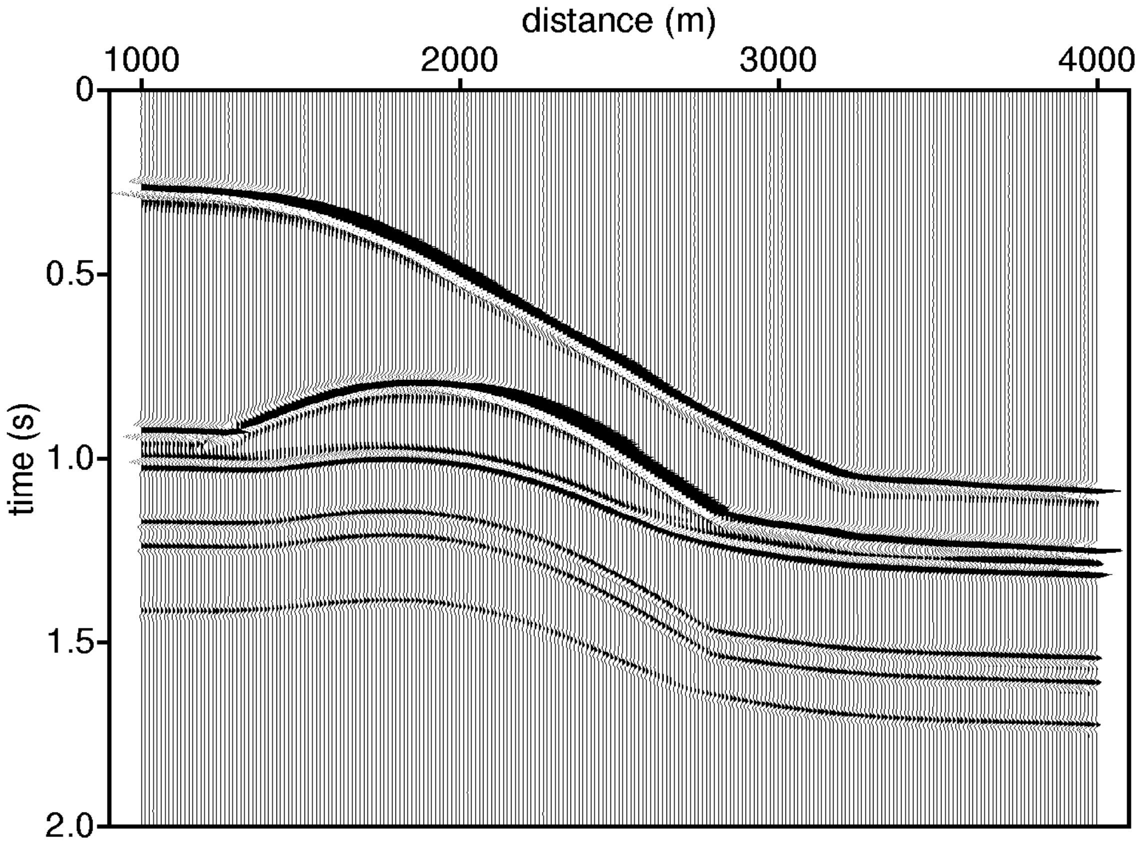
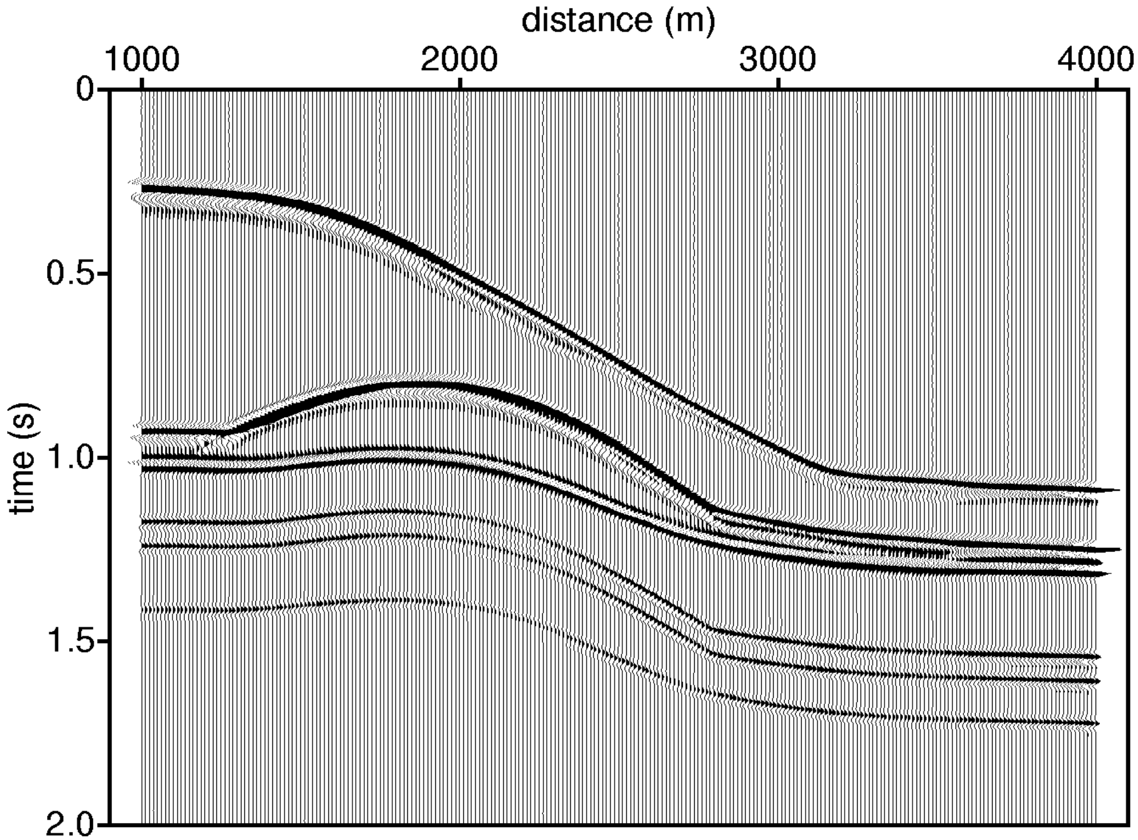
Primaries and multiple: stack



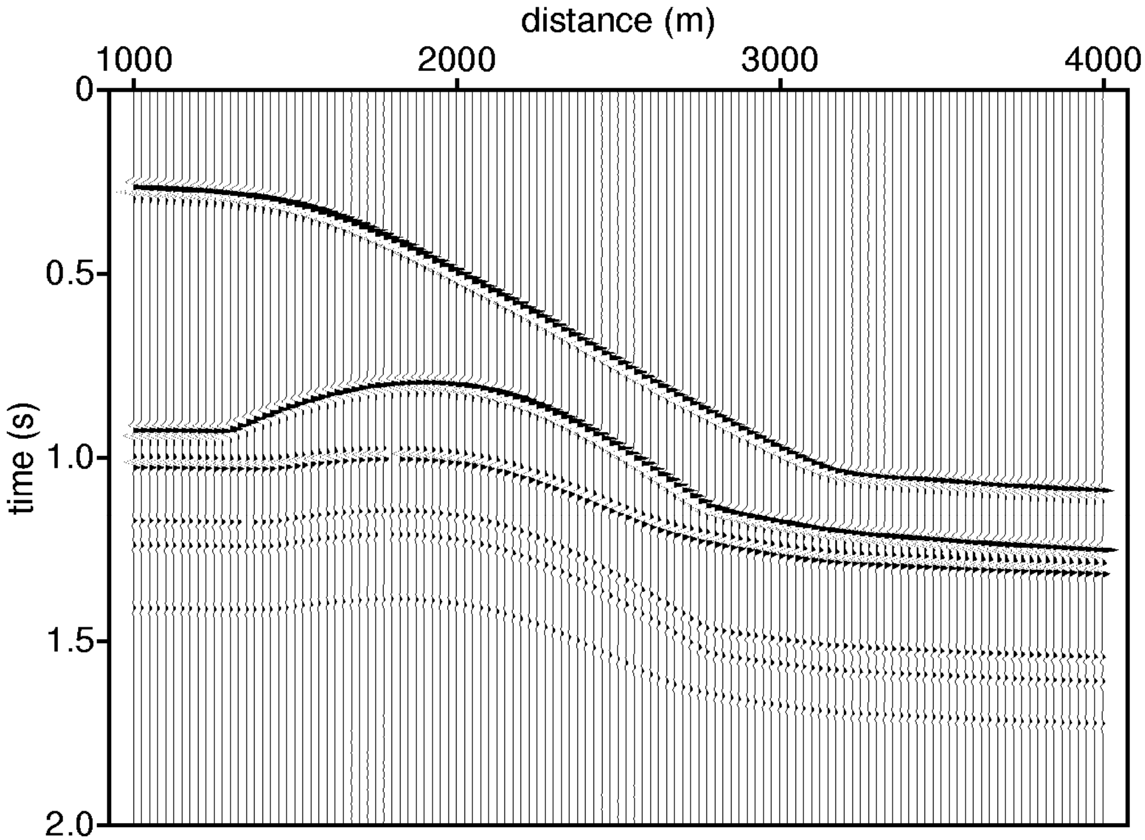
Stack



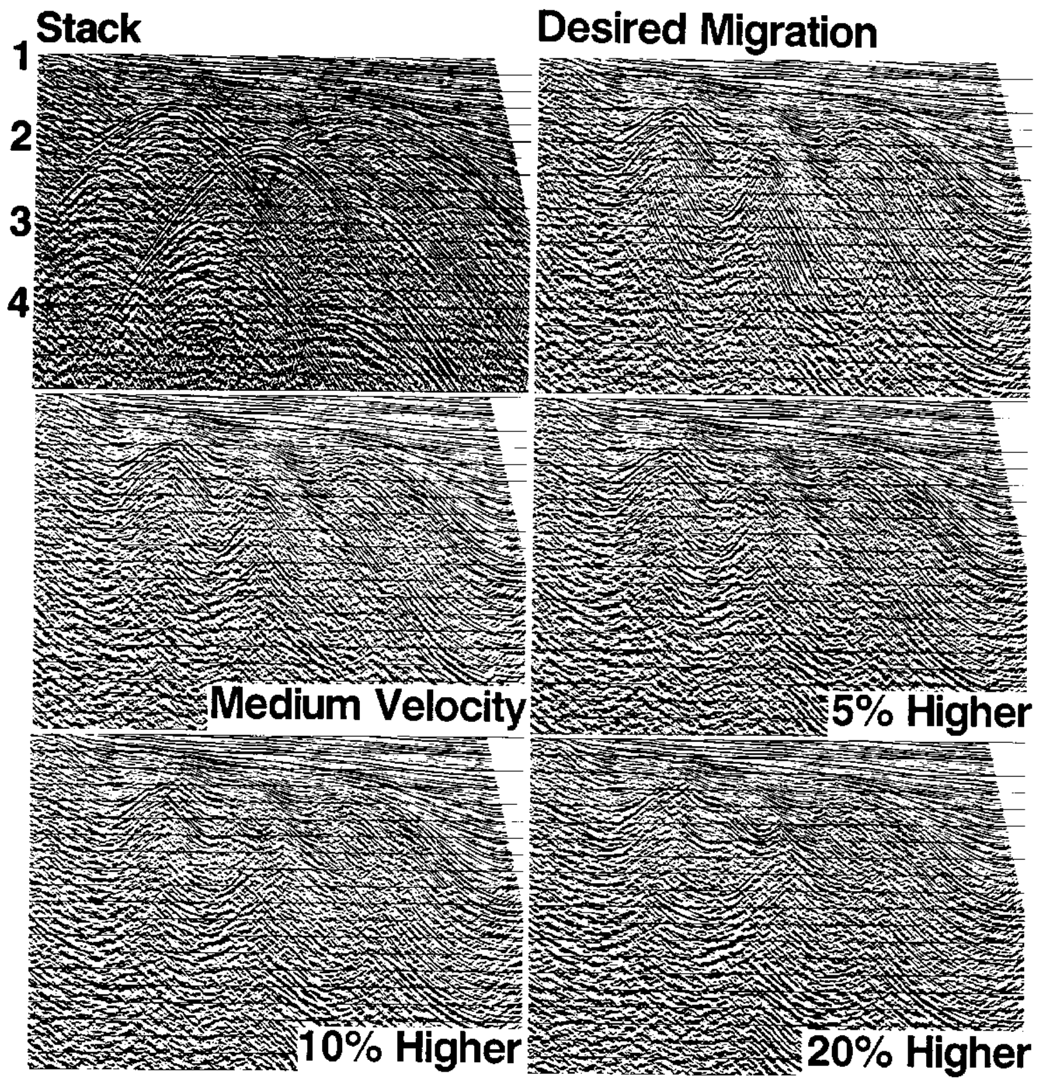
Stack: 7% wrong velocity



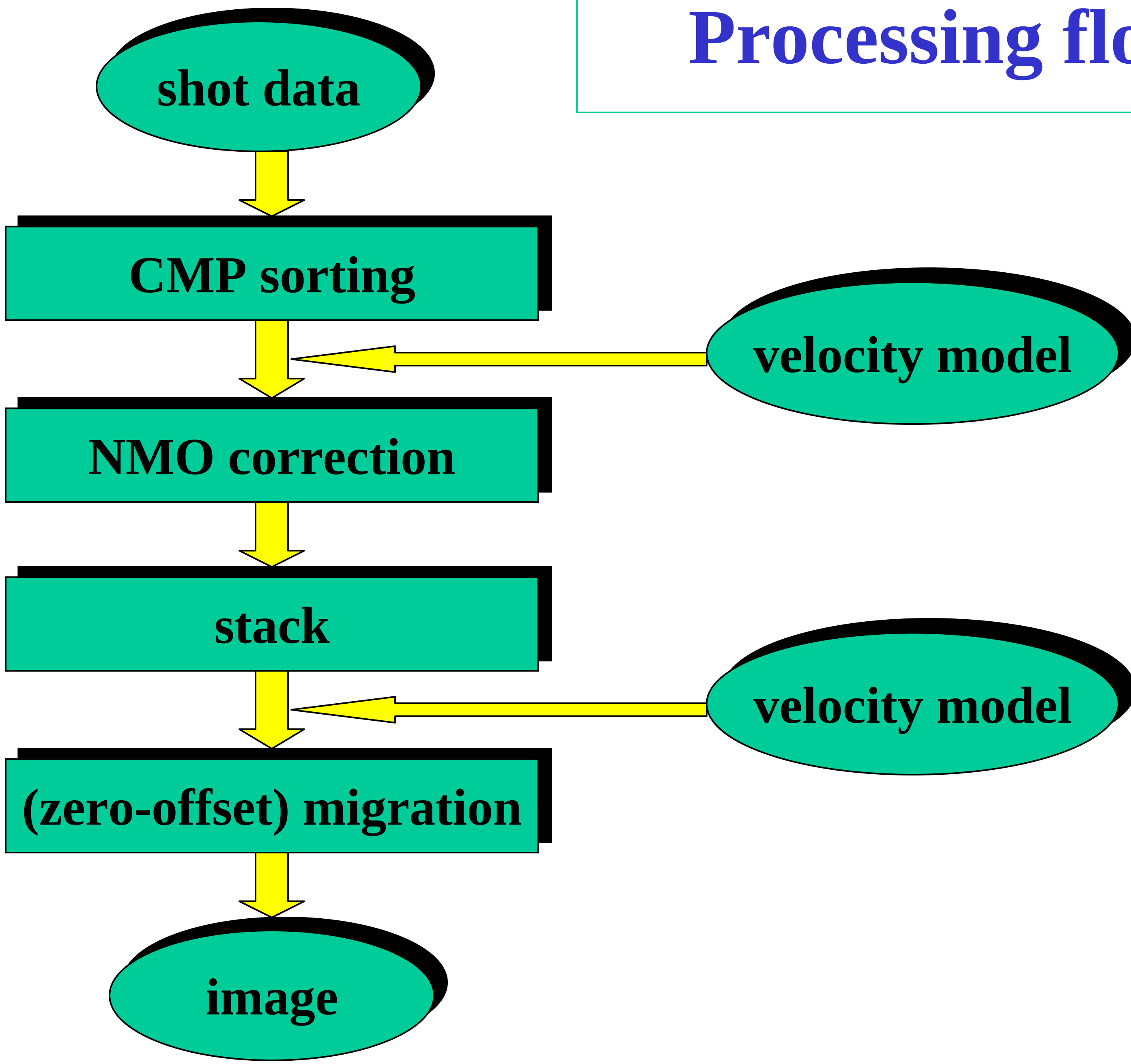
Zero-offset gather (no stacking)



Effect velocity on stack/migration



Processing flow



Migration (zero-offset)

Stacked section is assumed to be zero-offset

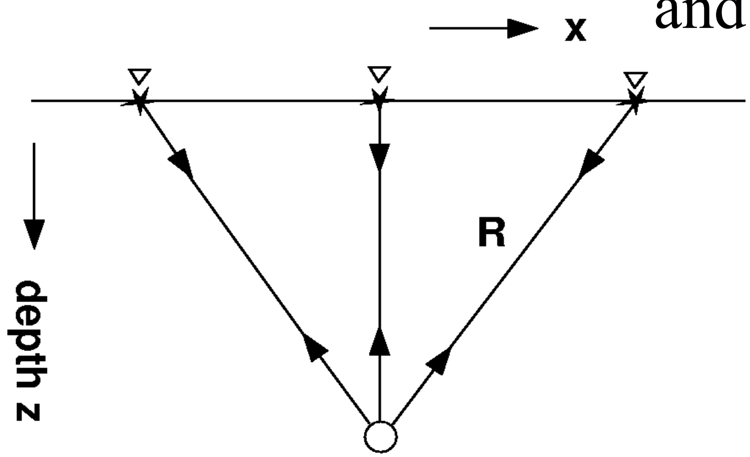
(as if you shot with 1 geophone, and geophone at shot position)

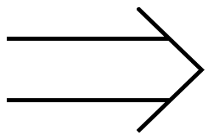
A zero-offset section:

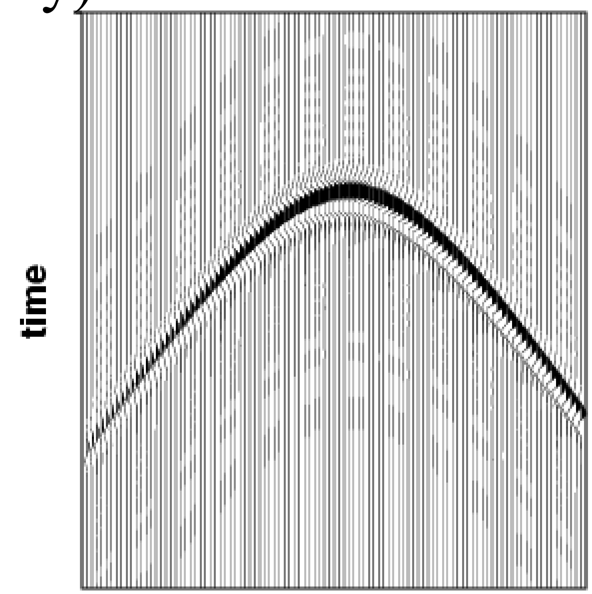
energy is still not focussed !!!

Diffractor: zero-offset

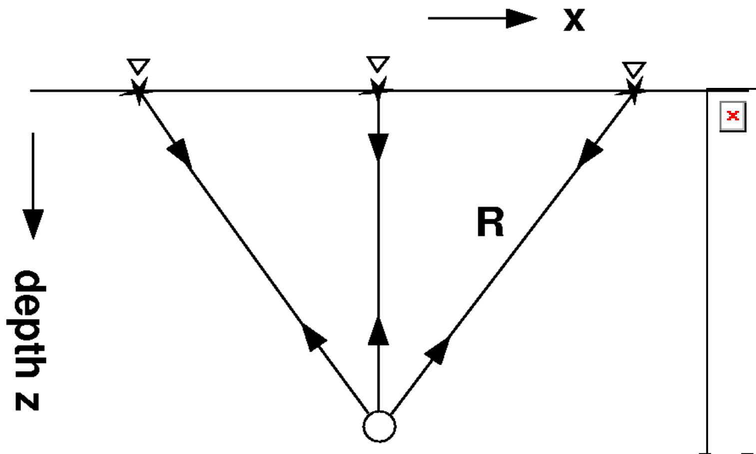
Modelling
(we know the Earth:
Position of diffractor
and seismic velocity)



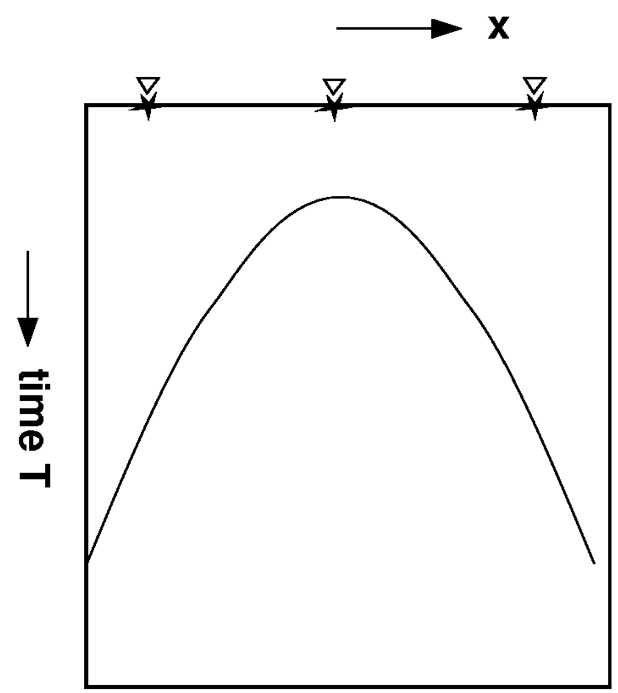




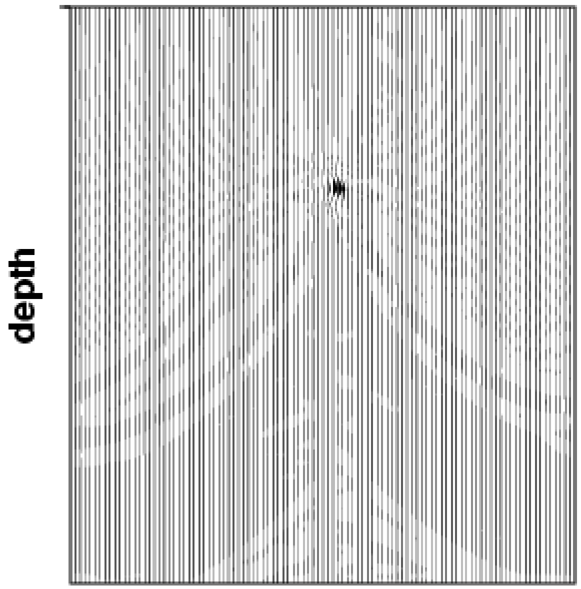
Diffractor: zero-offset

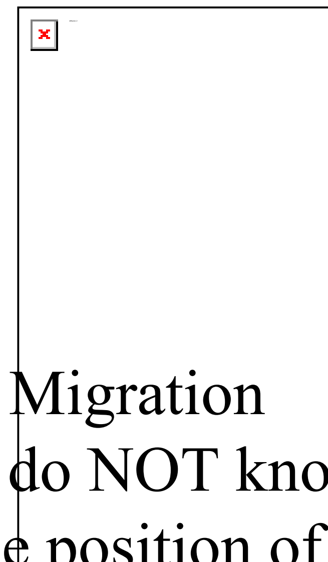


Migration
(we do NOT know
the position of
diffractor, but do
know the velocity)

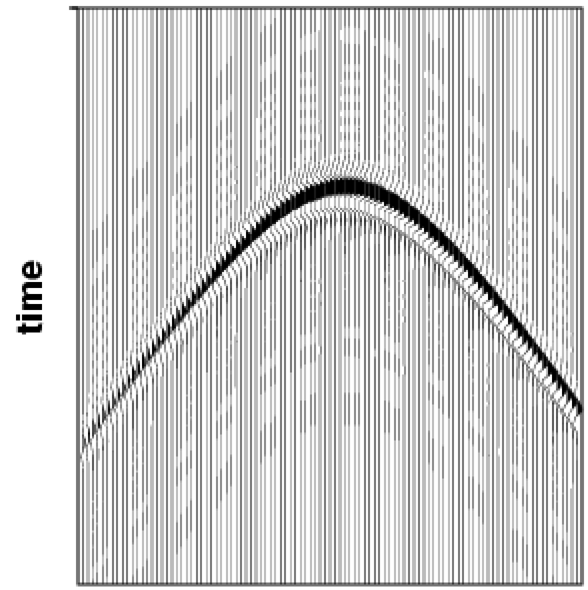


Diffractor: zero-offset

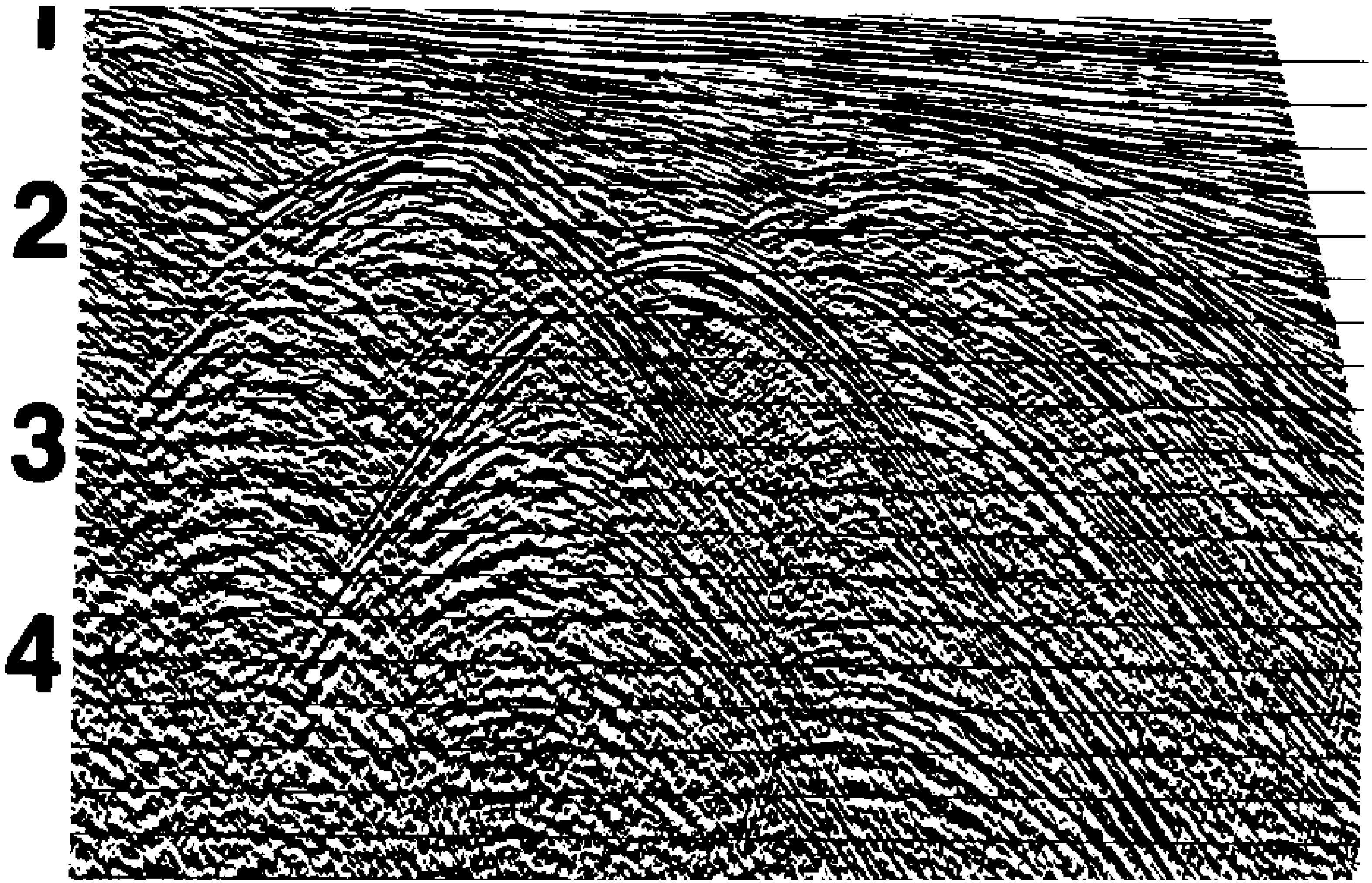




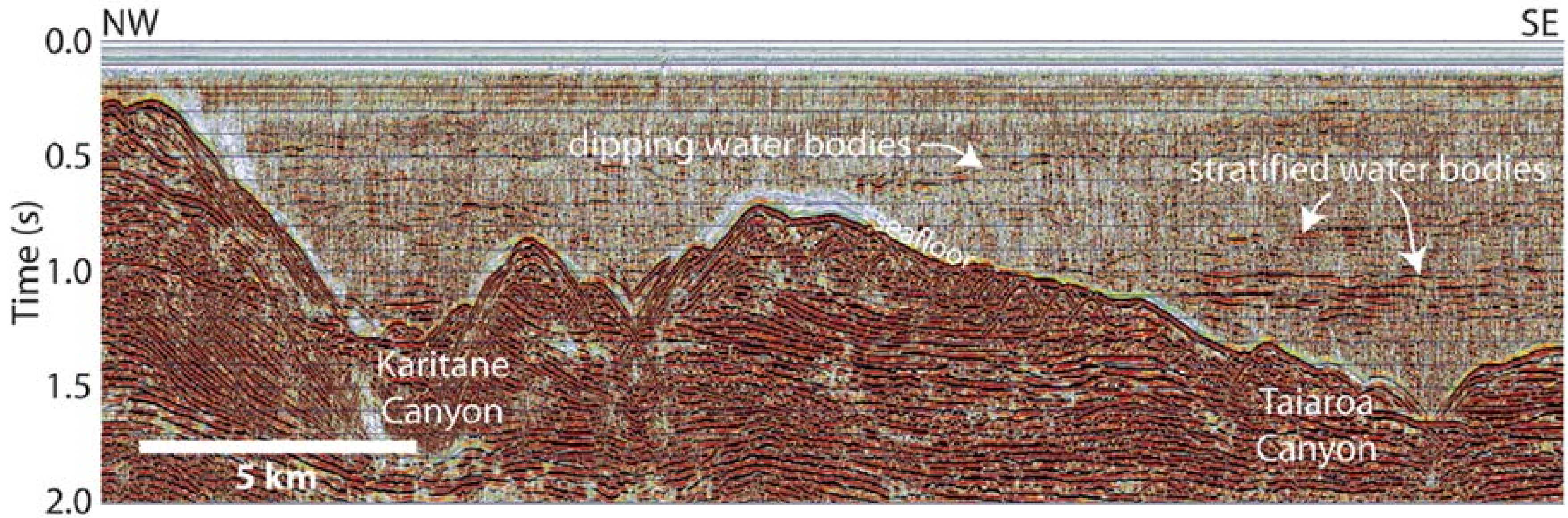
Migration
(we do NOT know the position of diffractor, but do know the velocity)



Diffractor: zero-offset stack



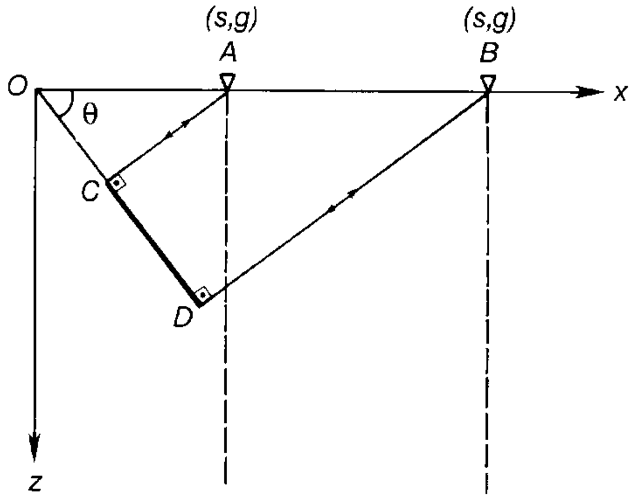
Diffractor: zero-offset stack



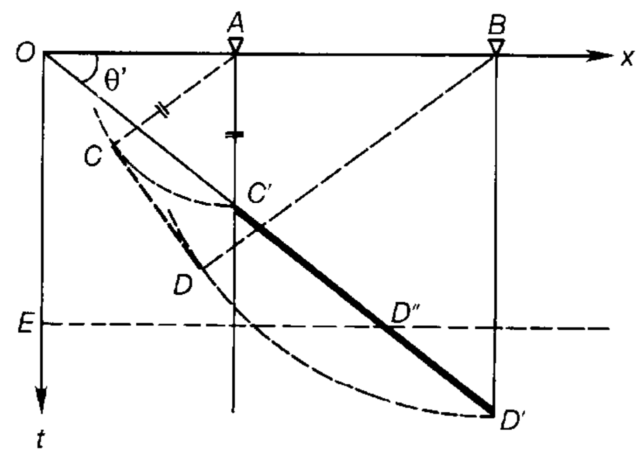
(60-fold stack)

Migration on dipping reflector

Modelling
(we know the Earth:
Position of reflector
and seismic velocity)

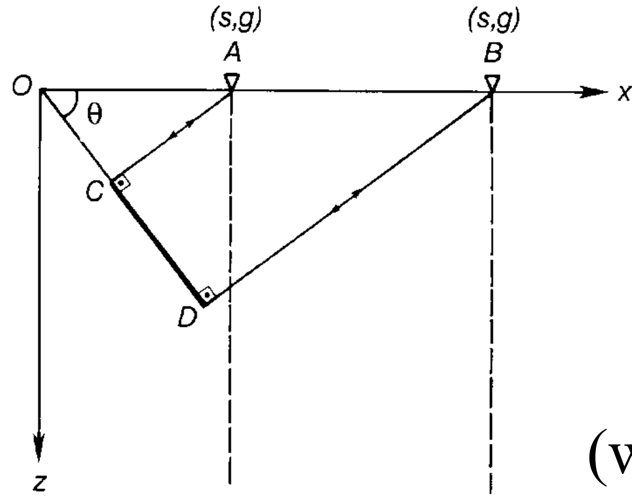


(a)



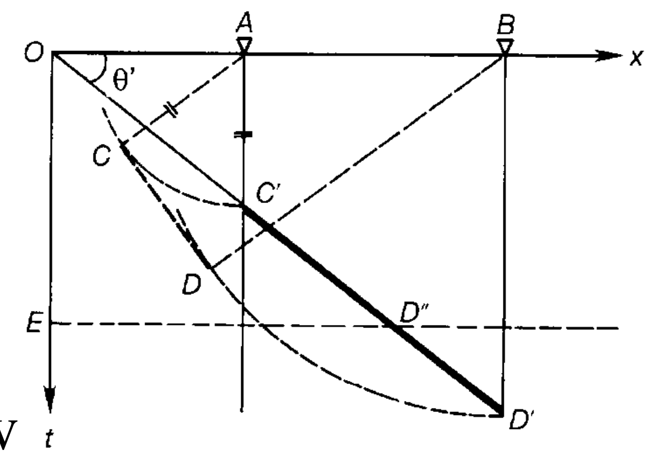
(b)

Migration on dipping reflector



(a)

Migration
(we do NOT know
position of reflector,
but do know
seismic velocity)



(b)

Migration on piece of dipping reflector:

- Moves piece up-dip

- Makes dip steeper

- Makes piece shorter

Migration on dipping reflector

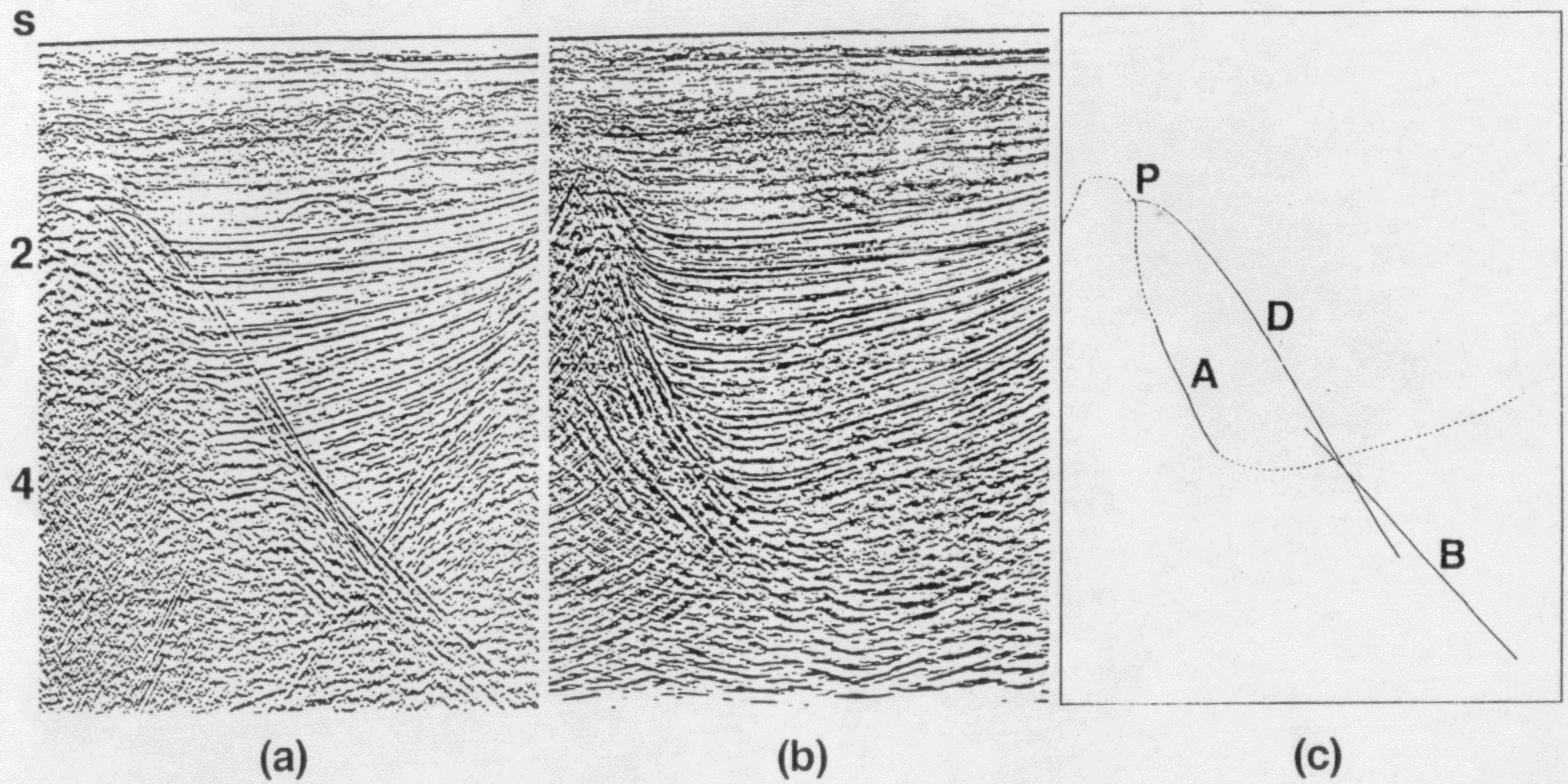
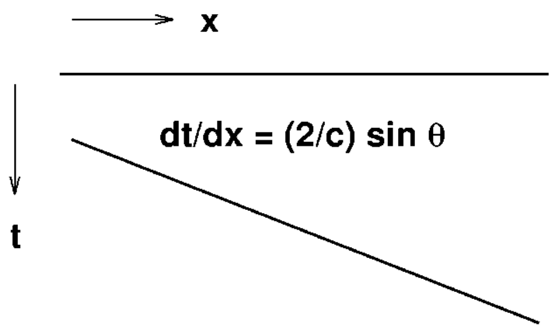


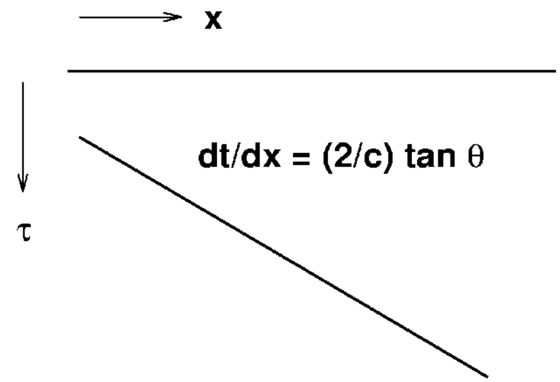
FIG. 4-1. (a) CMP stack, (b) migration, (c) sketch of a prominent diffraction D and a dipping event before (B) and after (A) migration. Migration moves the dipping event B to its assumed true subsurface position A and collapses the diffraction D to its apex P. The dotted line indicates the boundary of the salt dome.

Apparent dips

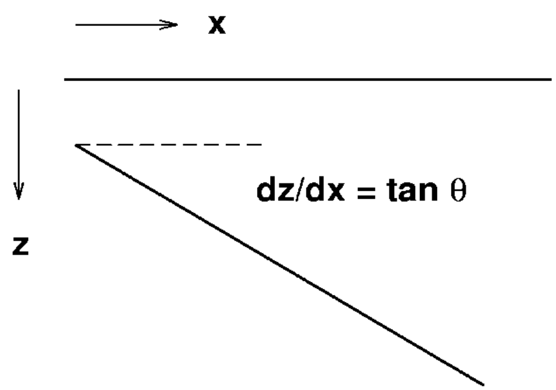
Zero-offset section:



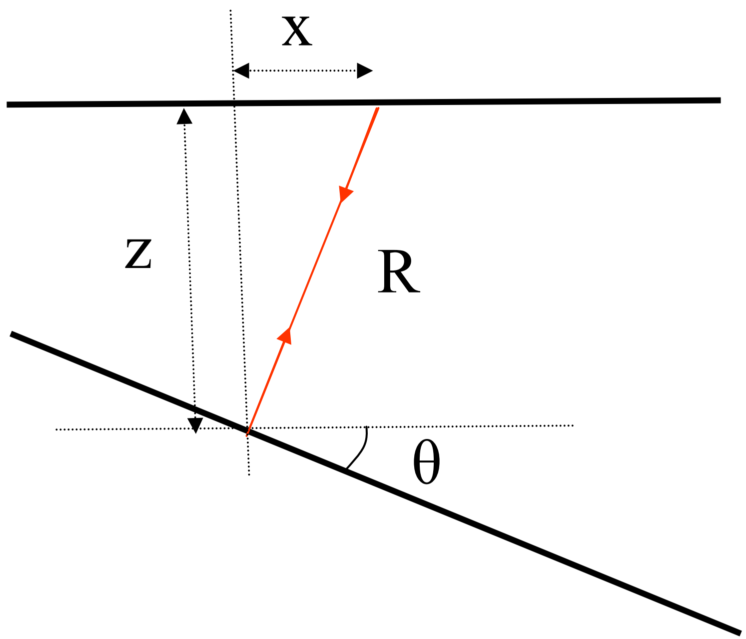
(time-) migrated section:



(depth-) migrated section = depth section:



Dip



$$T = 2\,R/c = 2\,\sqrt{(x^2+z^2)}/c$$

$$\partial T/\partial x = (2/c)\ \tfrac{1}{2}\ (x^2+z^2)^{-1/2}\ 2\,x$$

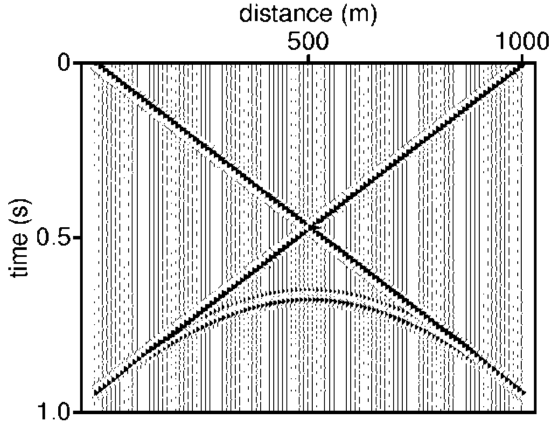
$$= (2/c)\ x/(x^2+z^2)^{1/2}$$

$$= (2/c)\ x/R$$

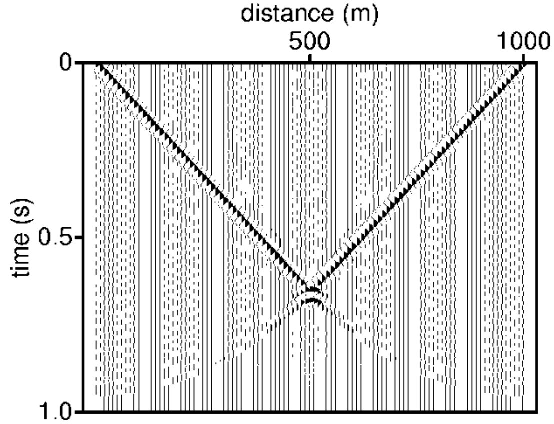
$\sin\theta = x/R$

So: $\partial T/\partial x = 2/c \sin\theta$

Double-dip

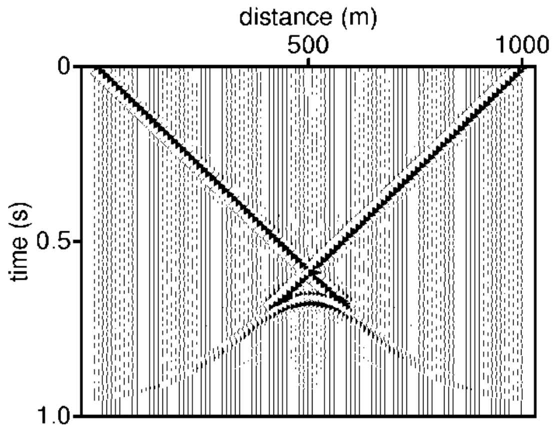


Zero-offset section:
before migration

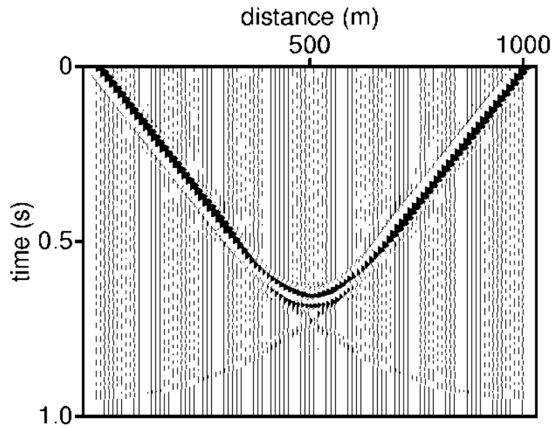


After migration

Double-dip (2)

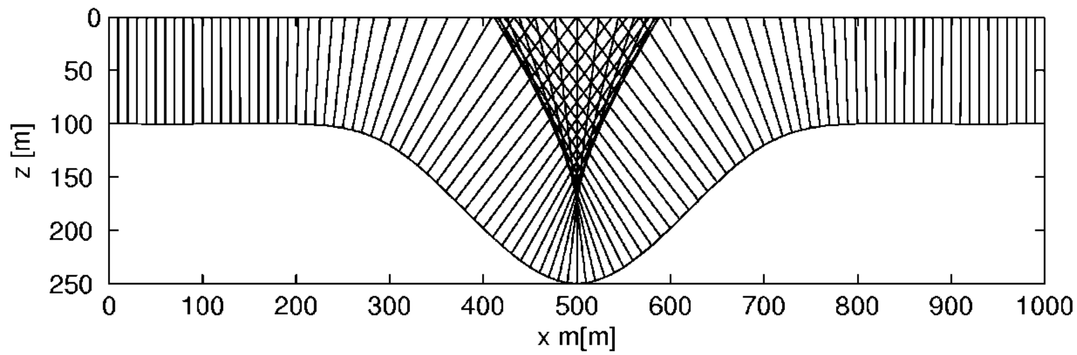


Migration with too
low velocity

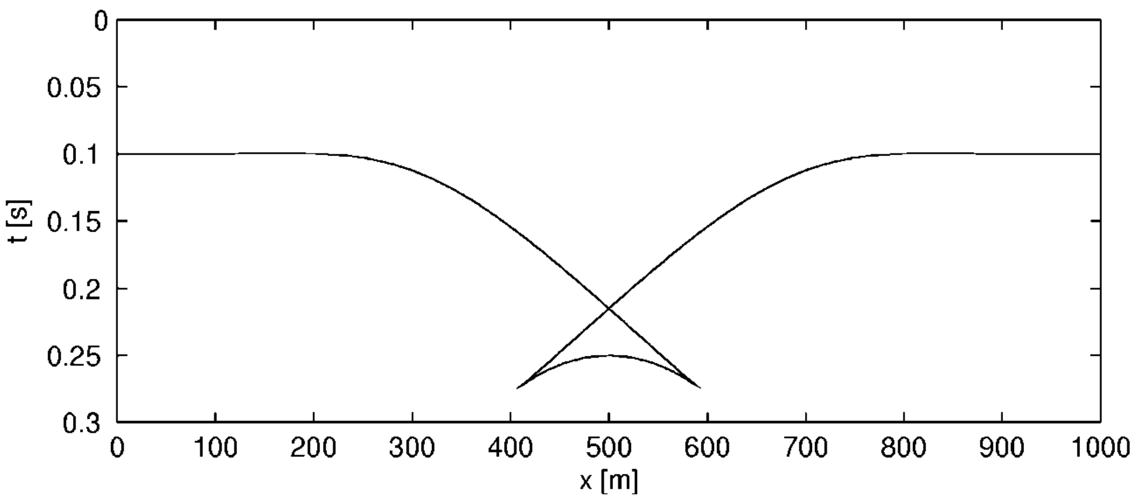


Migration with too
high velocity

Syncline

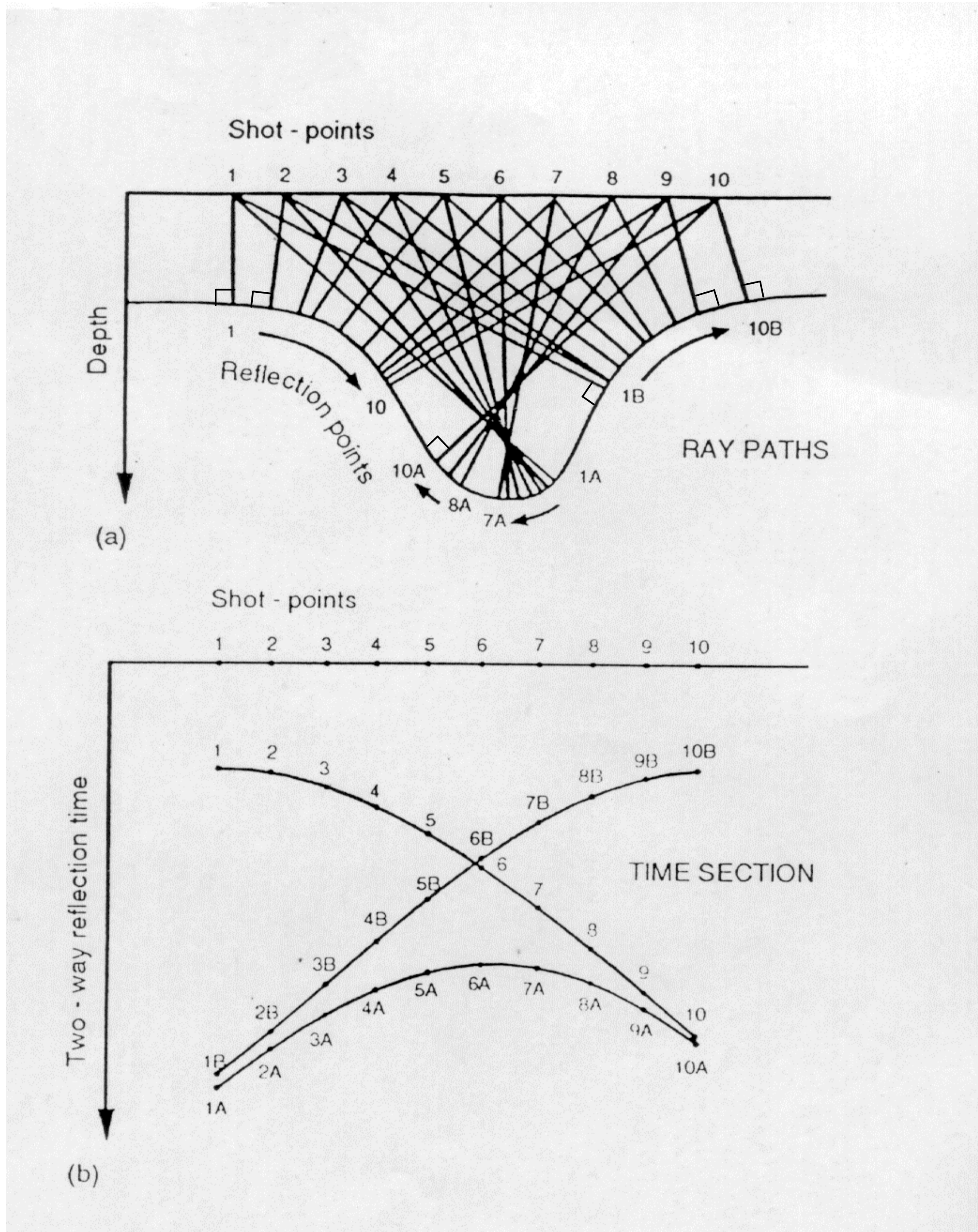


0
50
100
150
200
250
z [m]
0 100 200 300 400 500 600 700 800 900 1000
x m[m]

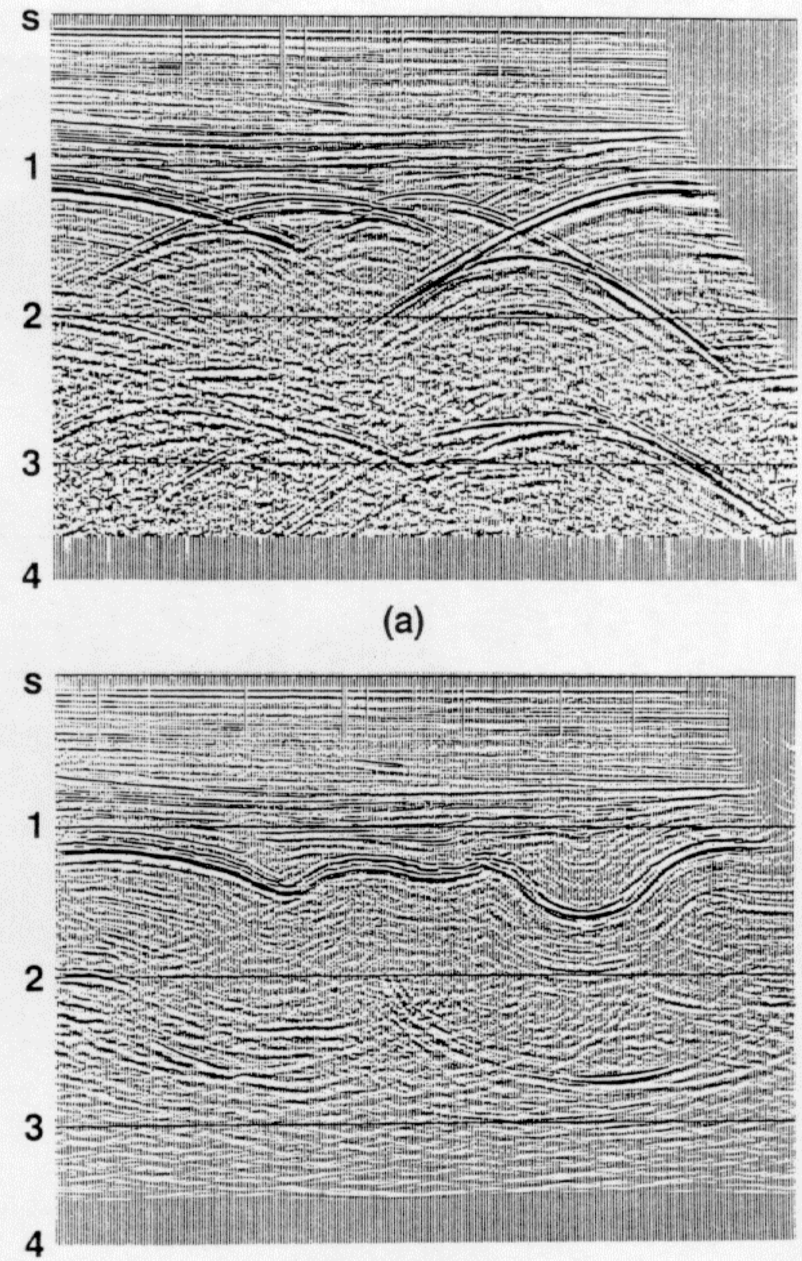


0
0.05
0.1
0.15
0.2
0.25
0.3
t [s]
0 100 200 300 400 500 600 700 800 900 1000
x [m]

Syncline model with ray paths



Syncline: real data example

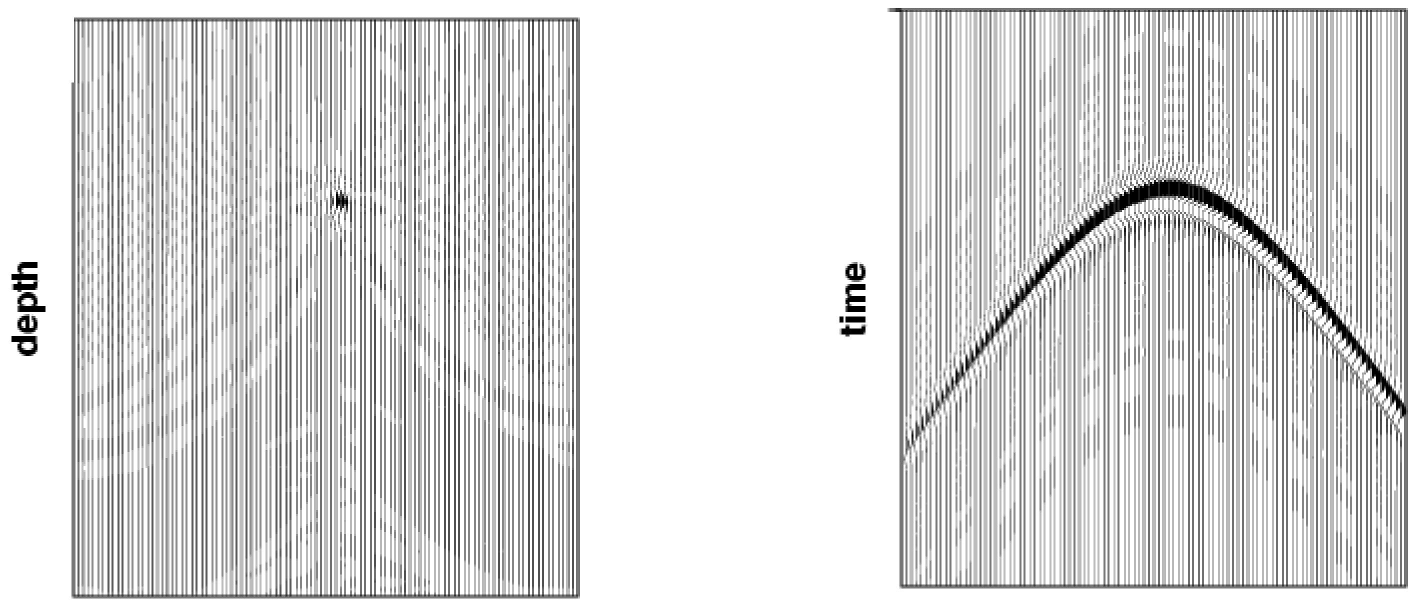


(a)
(b)

Migration:

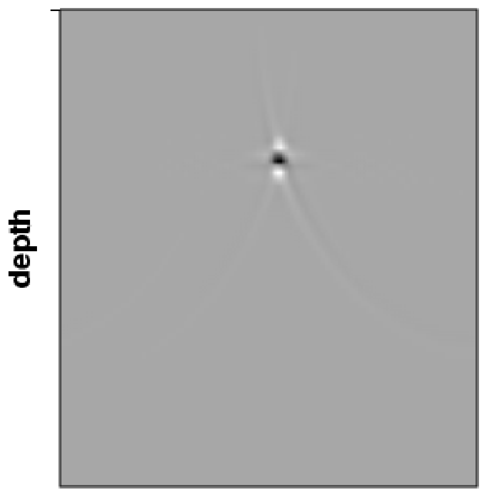
HOW ??

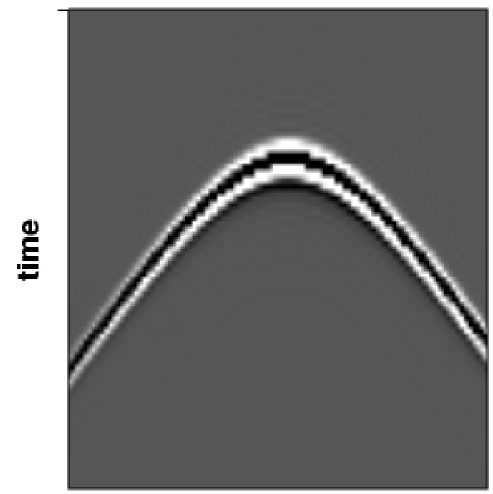
1 Diffractor: zero-offset



“Wiggle plot”:
Signals next to each other

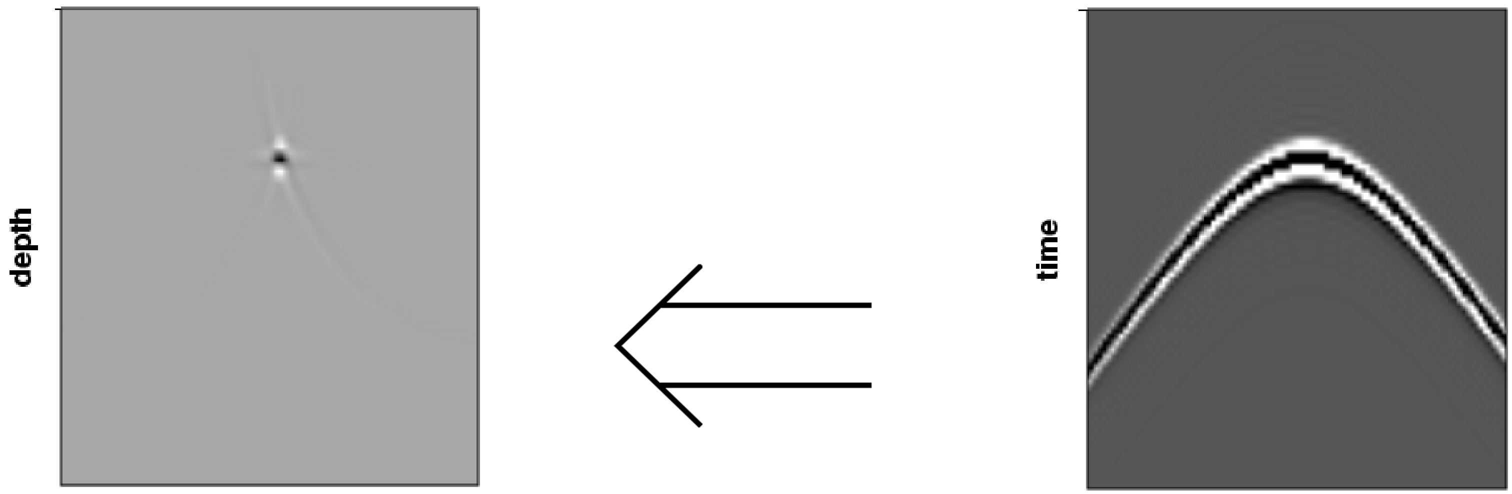
1 diffractor: zero-offset





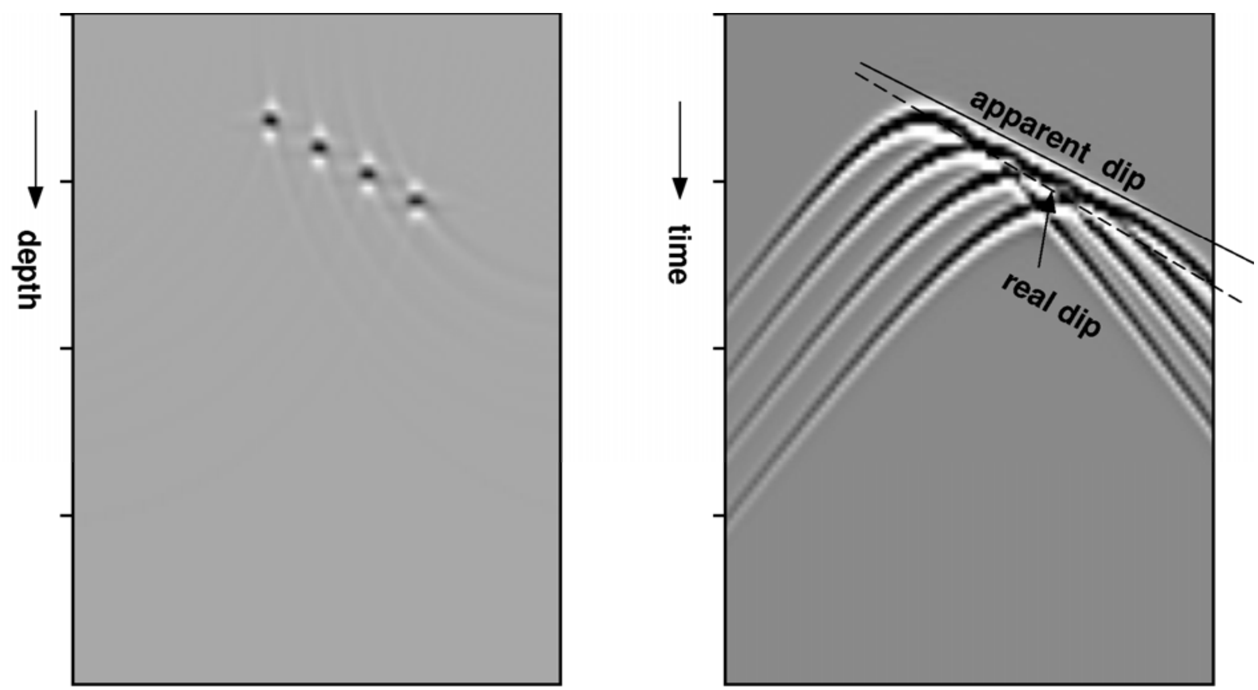
“Image plot”:
Like a photograph

1 diffractor: zero-offset

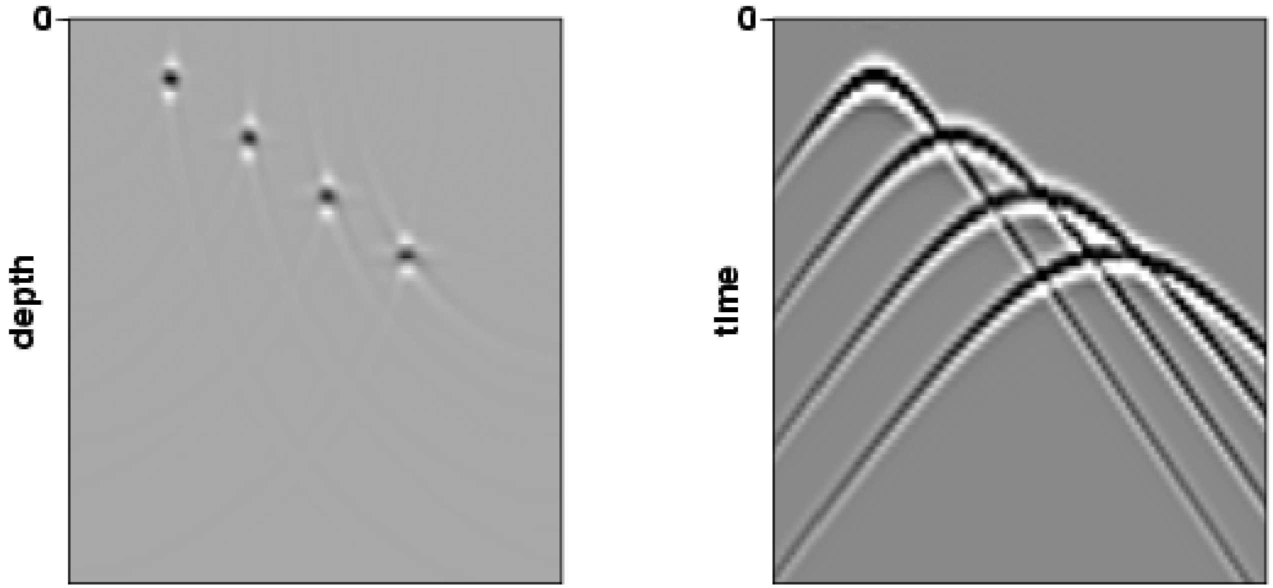


Migration:
Add along hyperbola
(we *do* know velocity)

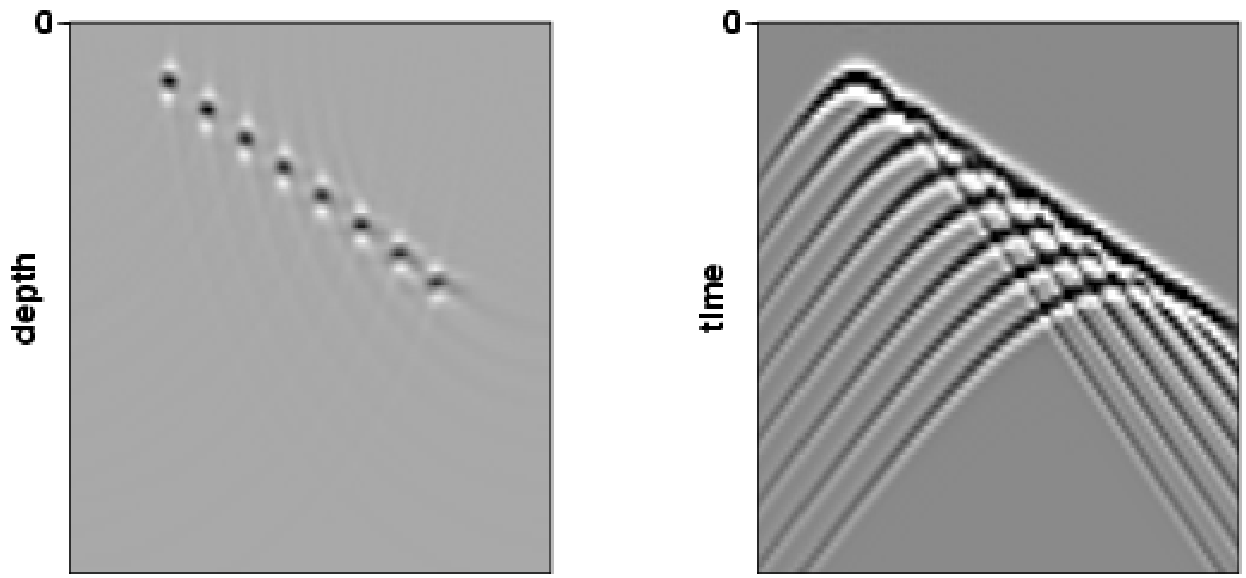
4 diffractors: zero-offset



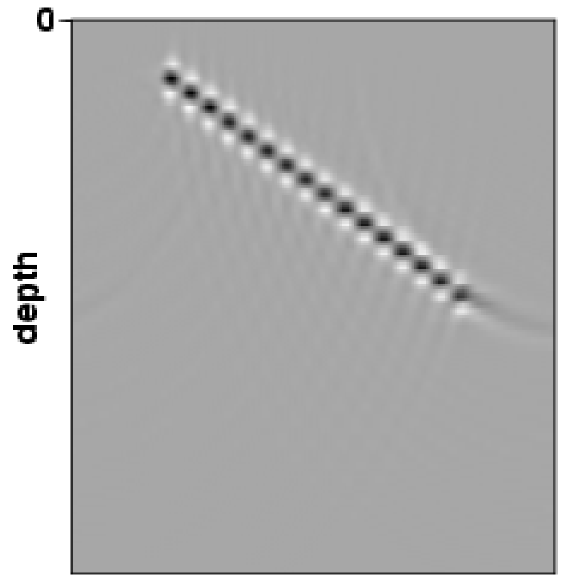
4 diffractors: zero-offset

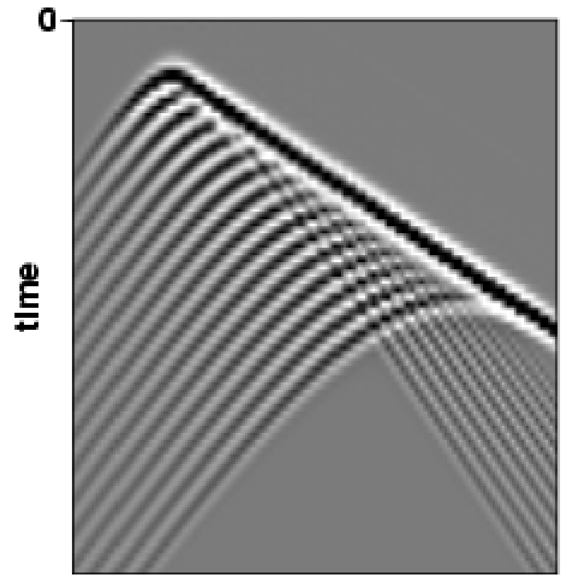


8 diffractors: zero-offset

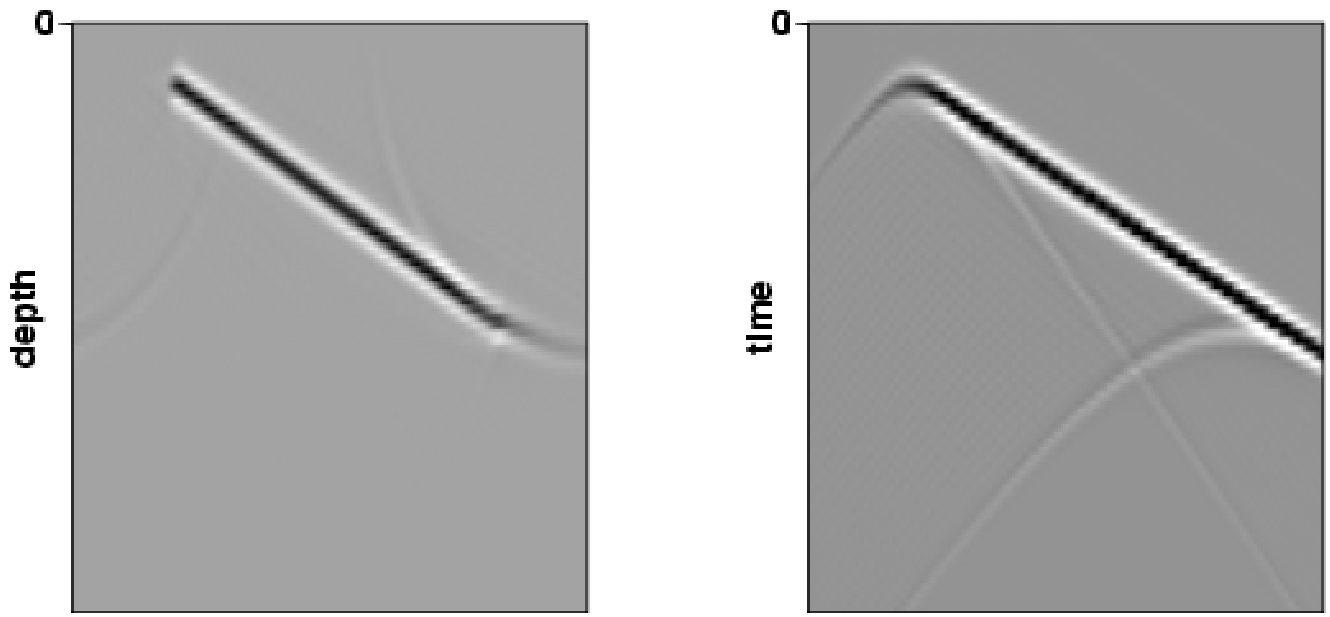


16 diffractors: zero-offset

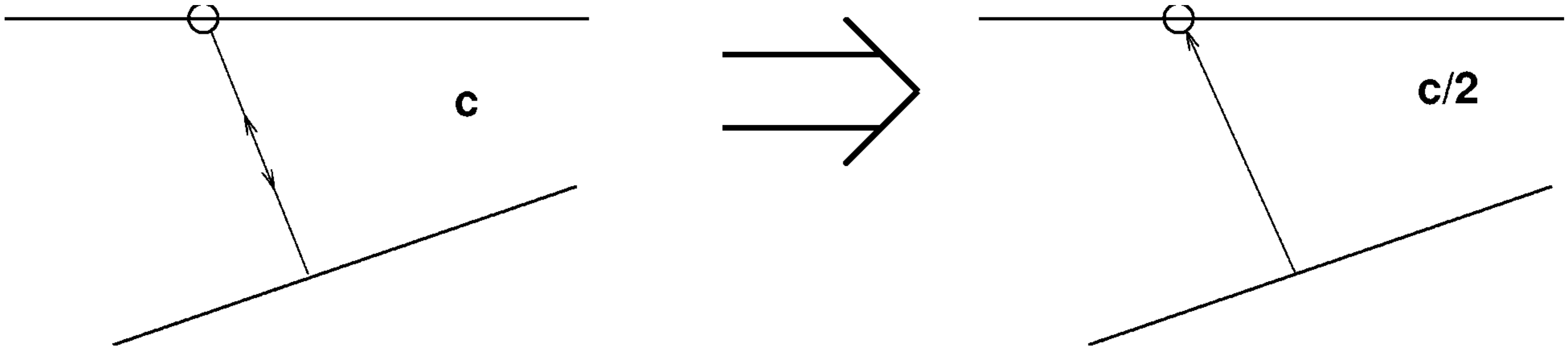




32 diffractors: zero-offset

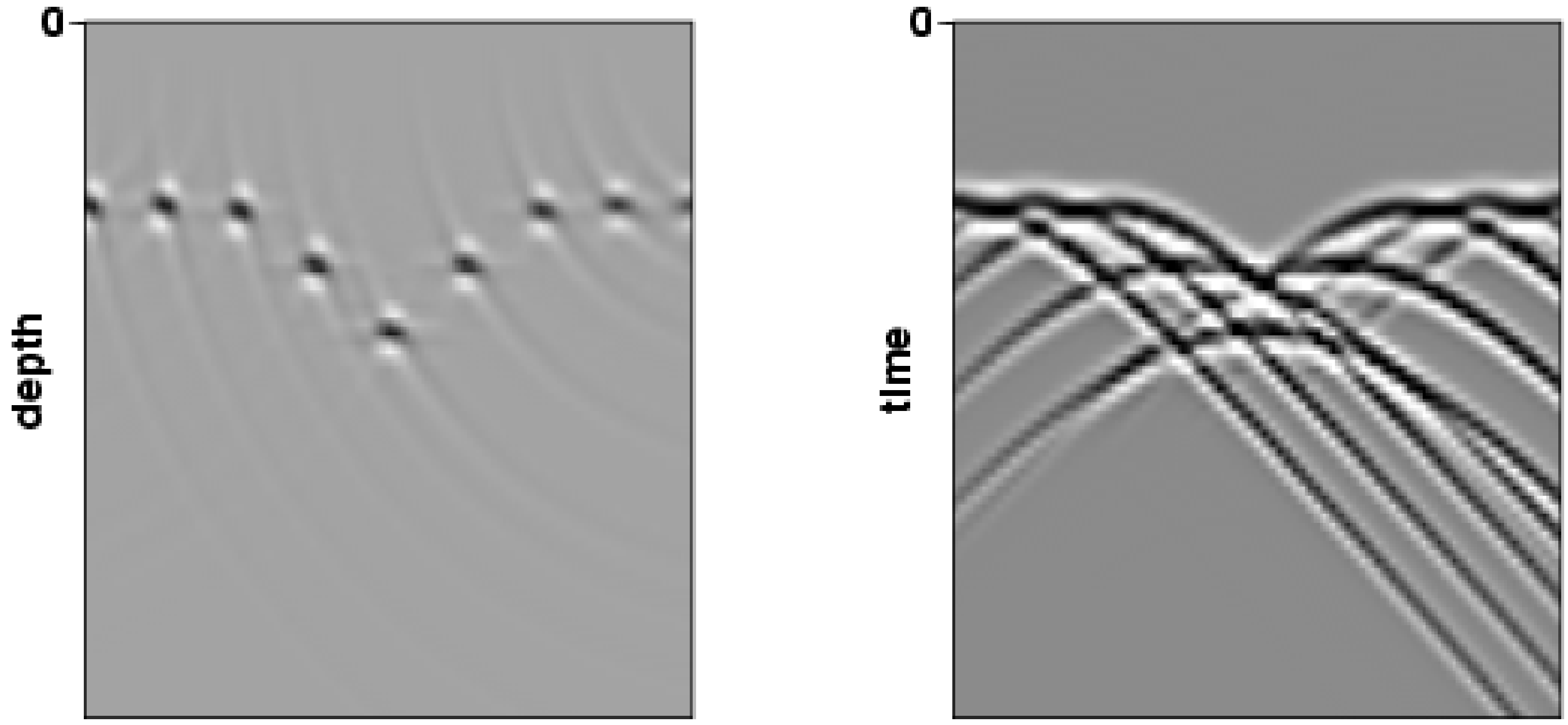


Exploding-reflector model

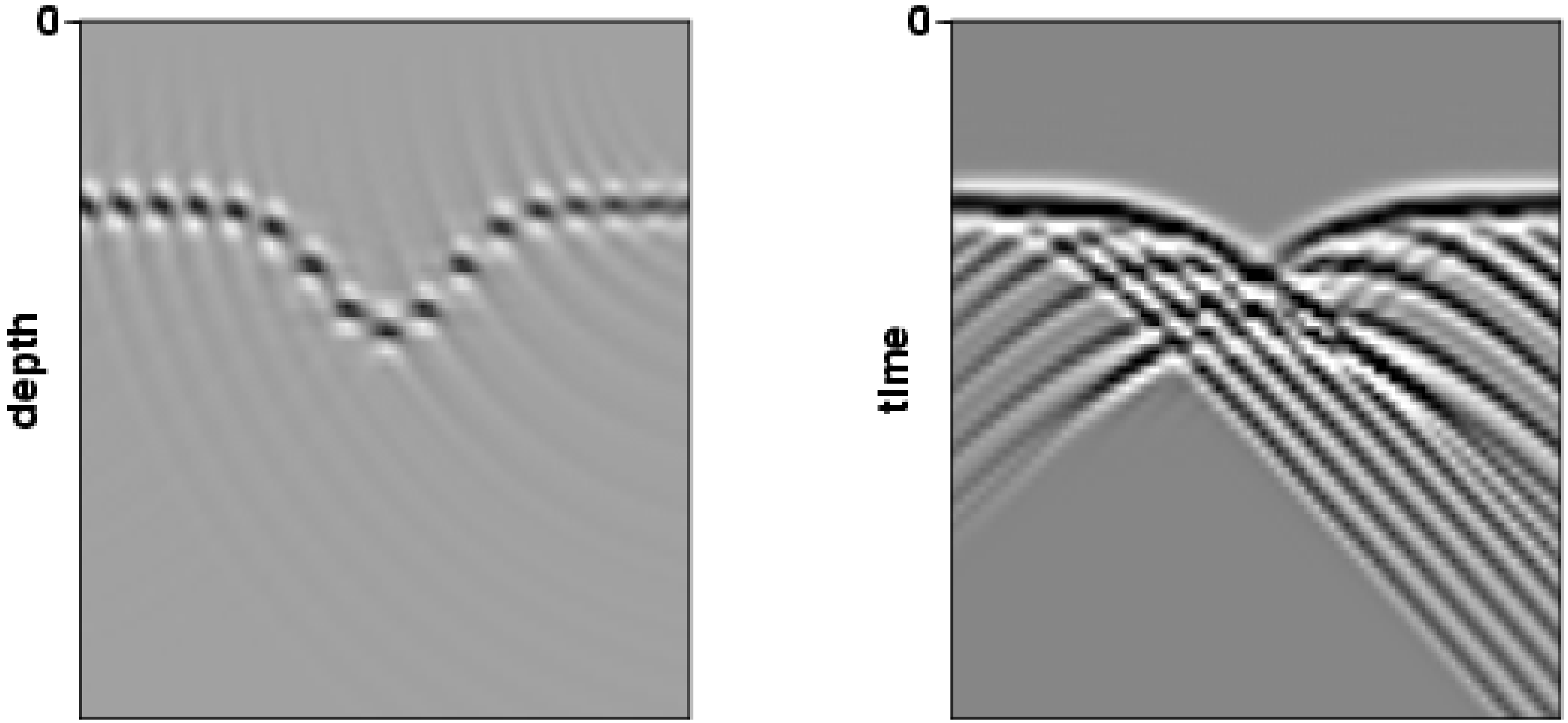


Zero-offset response can be simulated by putting sources at reflector and take half the medium velocity

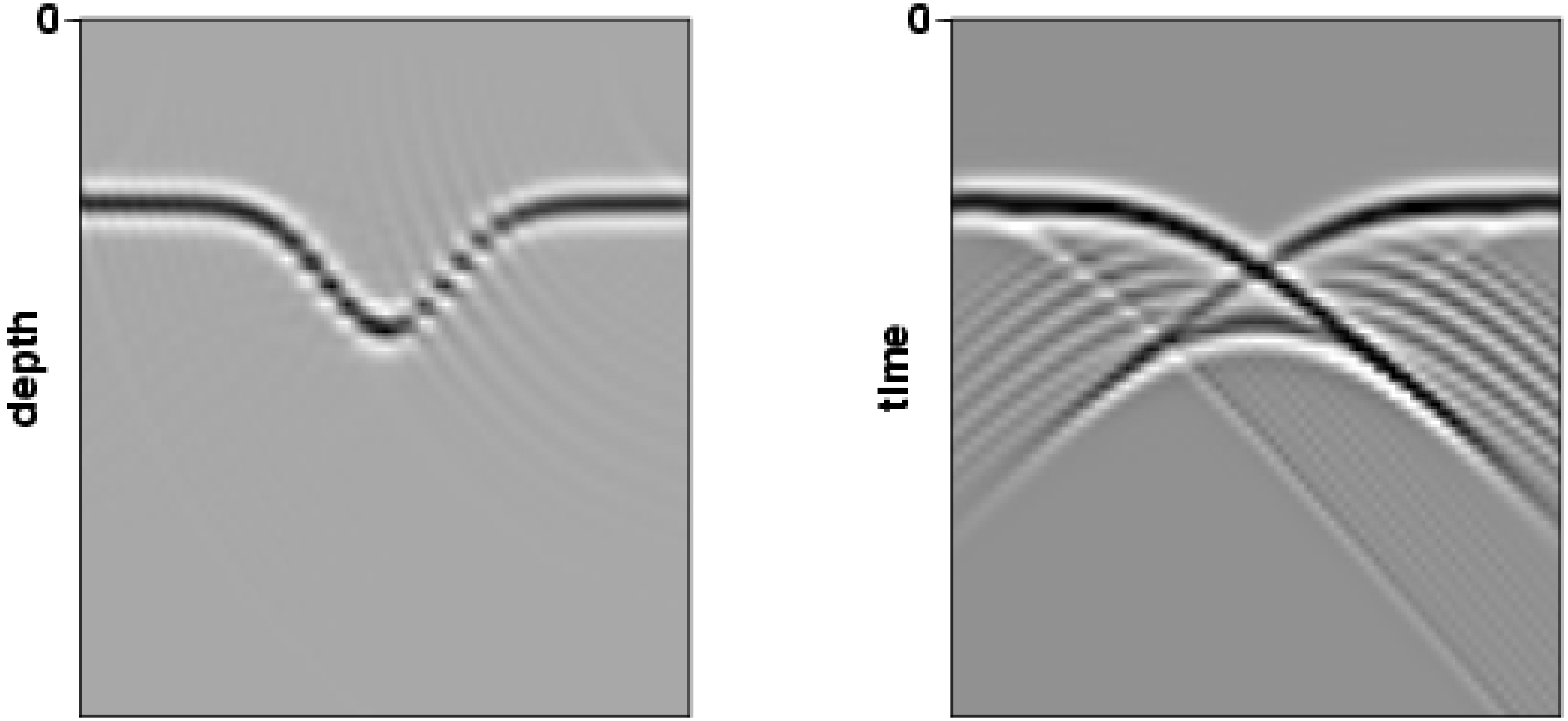
9 diffractors: zero-offset



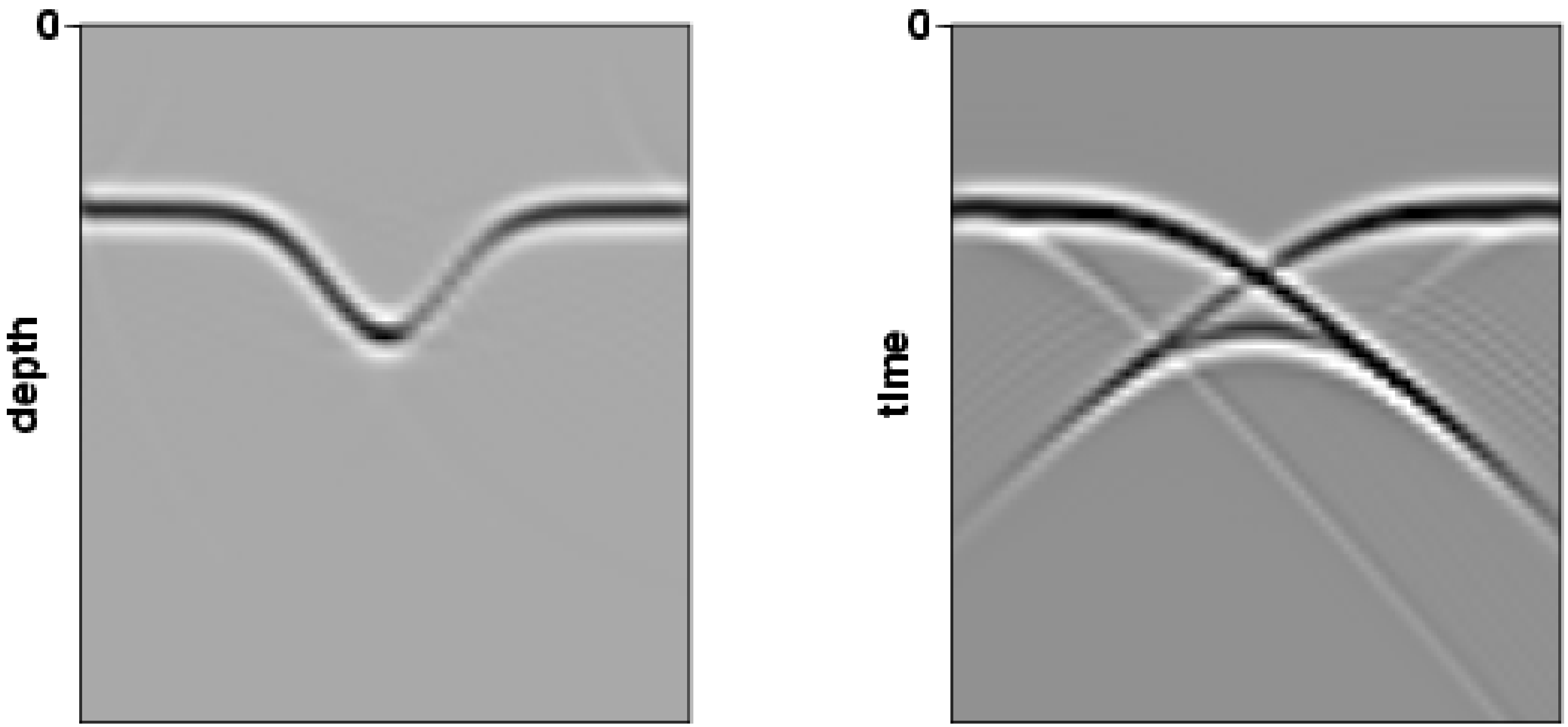
17 diffractors: zero-offset



33 diffractors: zero-offset



49 diffractors: zero-offset



Processing

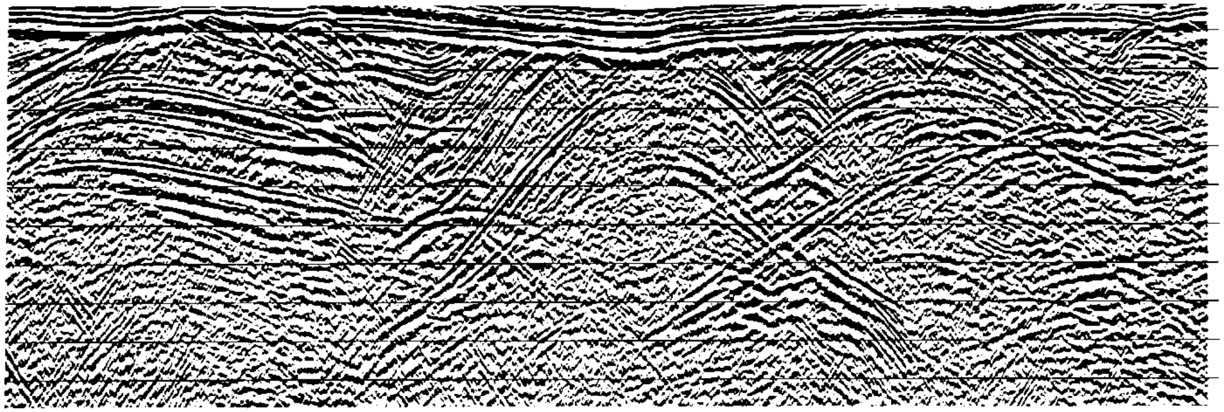
Input: Multi-offset shot records

Results of processing (after migration):

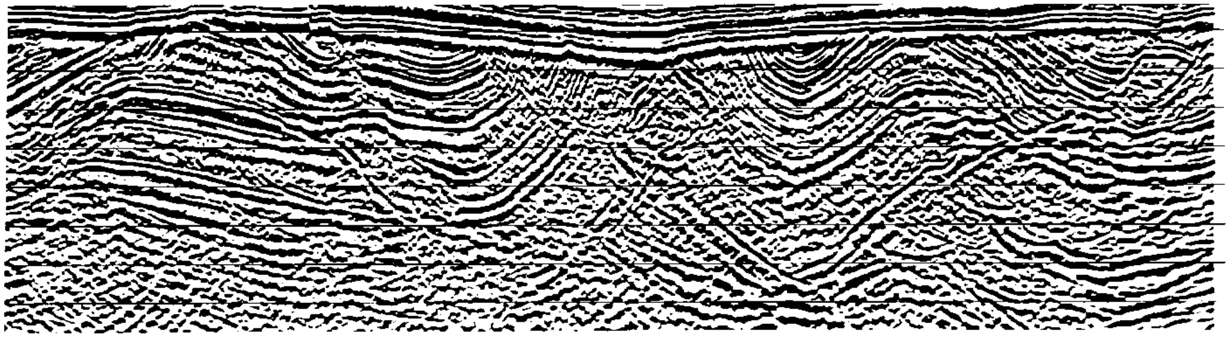
1. Structural map of impedance contrasts

2. Velocity model

Effect migration



(a)



(b)

Conversion from time to depth

Migration examples so far:

output section in **time**

This is called **time migration**

Still, data needs to be converted to depth: true earth

Simplest case: horizontal layers

From root-mean-square velocities to interval velocities:

Dix' formula

Dix' formula: from V_{RMS} to $V_{INTERVAL}$

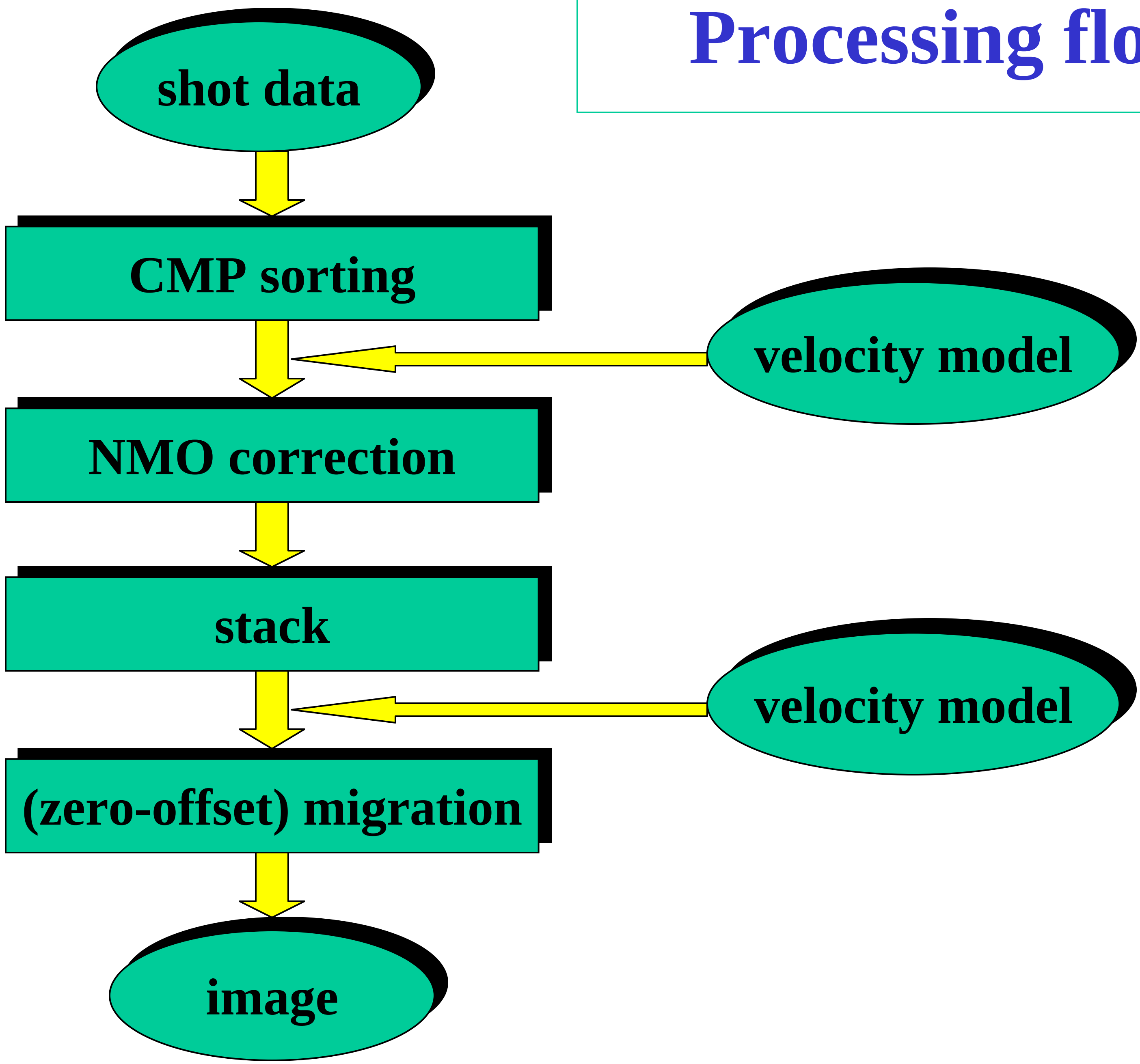
(pdf-eqs)

Conversion from time to depth via Dix' formula

Theoretically: valid for plane horizontal layers
(Theoretically: no migration necessary)

Practically: still works well for dipping reflectors and mild lateral velocity variations, but then:
AFTER (time) migration

Processing flow



Strategy for seismic migration

Why ?

In beginning: only RMS-velocity model known: very crude
→ time migration (relatively fast/cheap)

When one well available: better (interval-) velocity model
→ some depth migration possible (relatively slow/expensive)

When more wells available: good (interval-) velocity model known
→ pre-stack depth migration possible (slow/expensive !$!)

Strategy for seismic migration

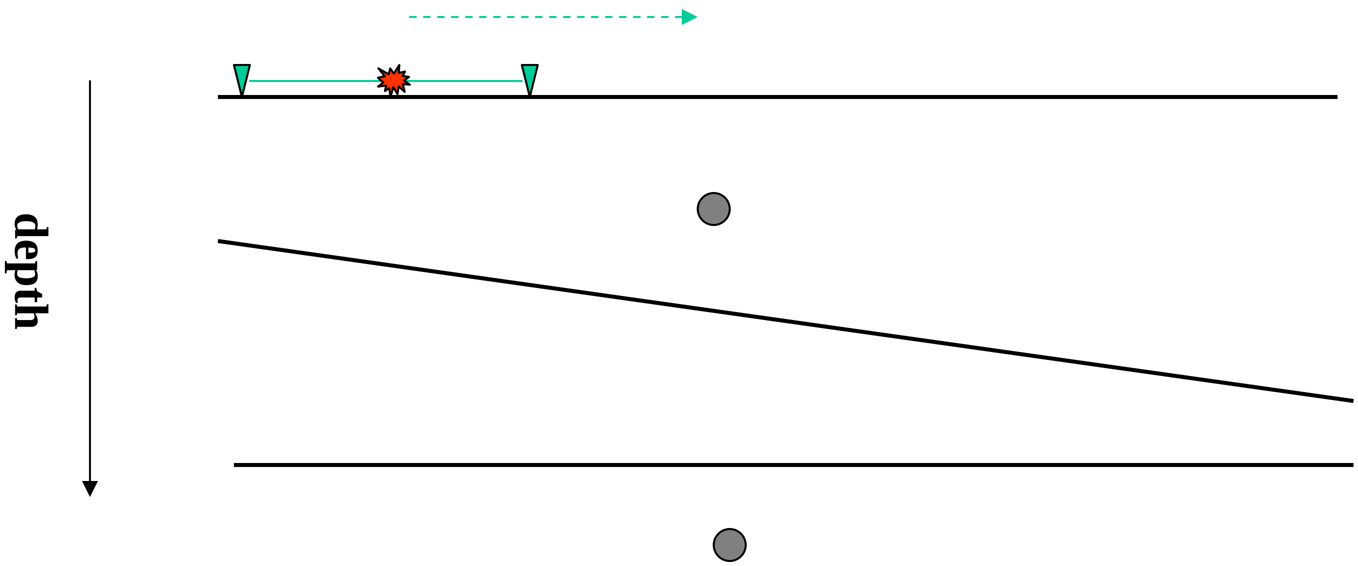
- **Simple structure: post-stack migration**
- **Complex structure: pre-stack migration**

  (such as DMO)

- **Small lateral velocity variations: time migration**
- **Large lateral velocity variations: depth migration**

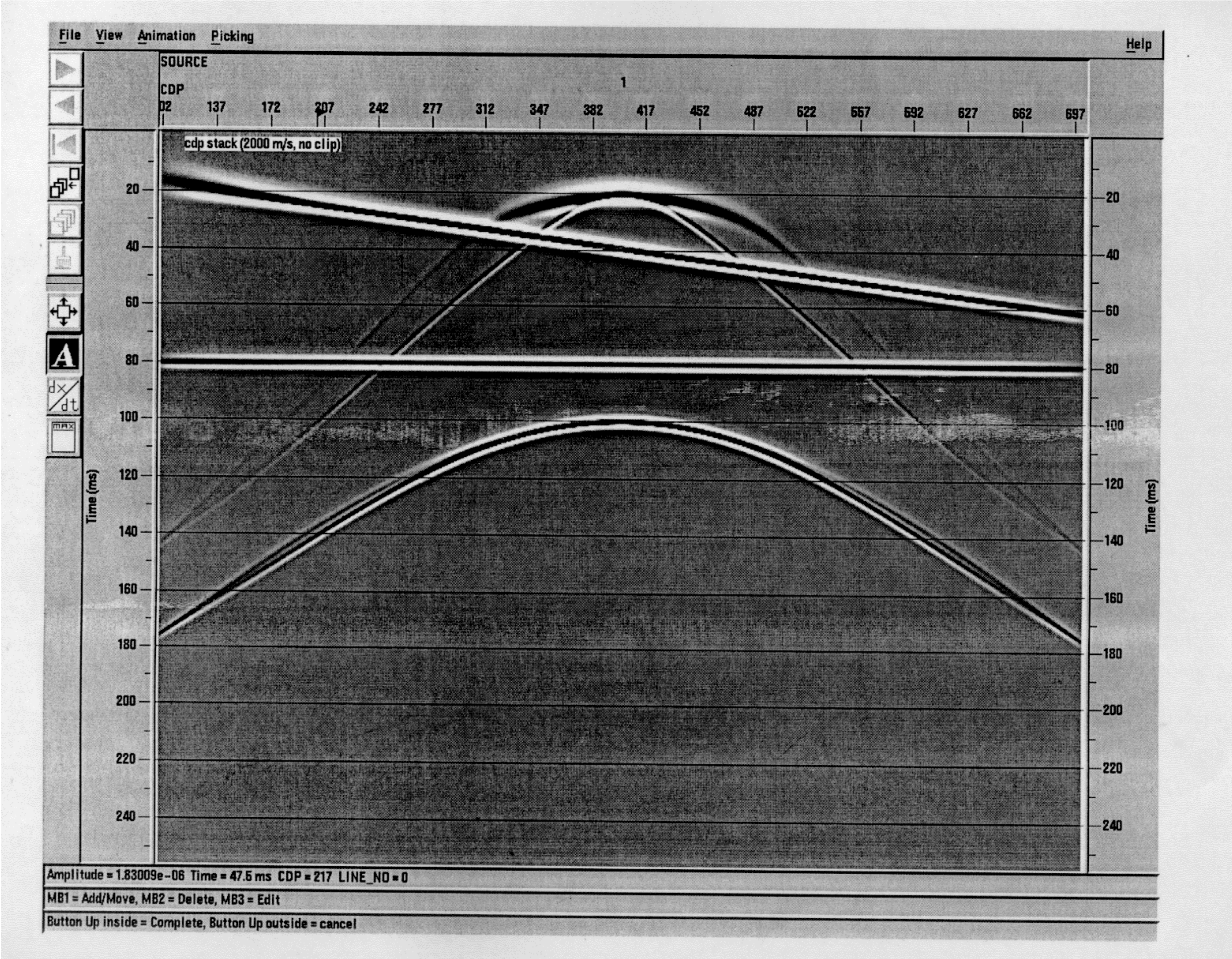
  (no hyperbolae any more)

Complex structure: simplest case of diffractors



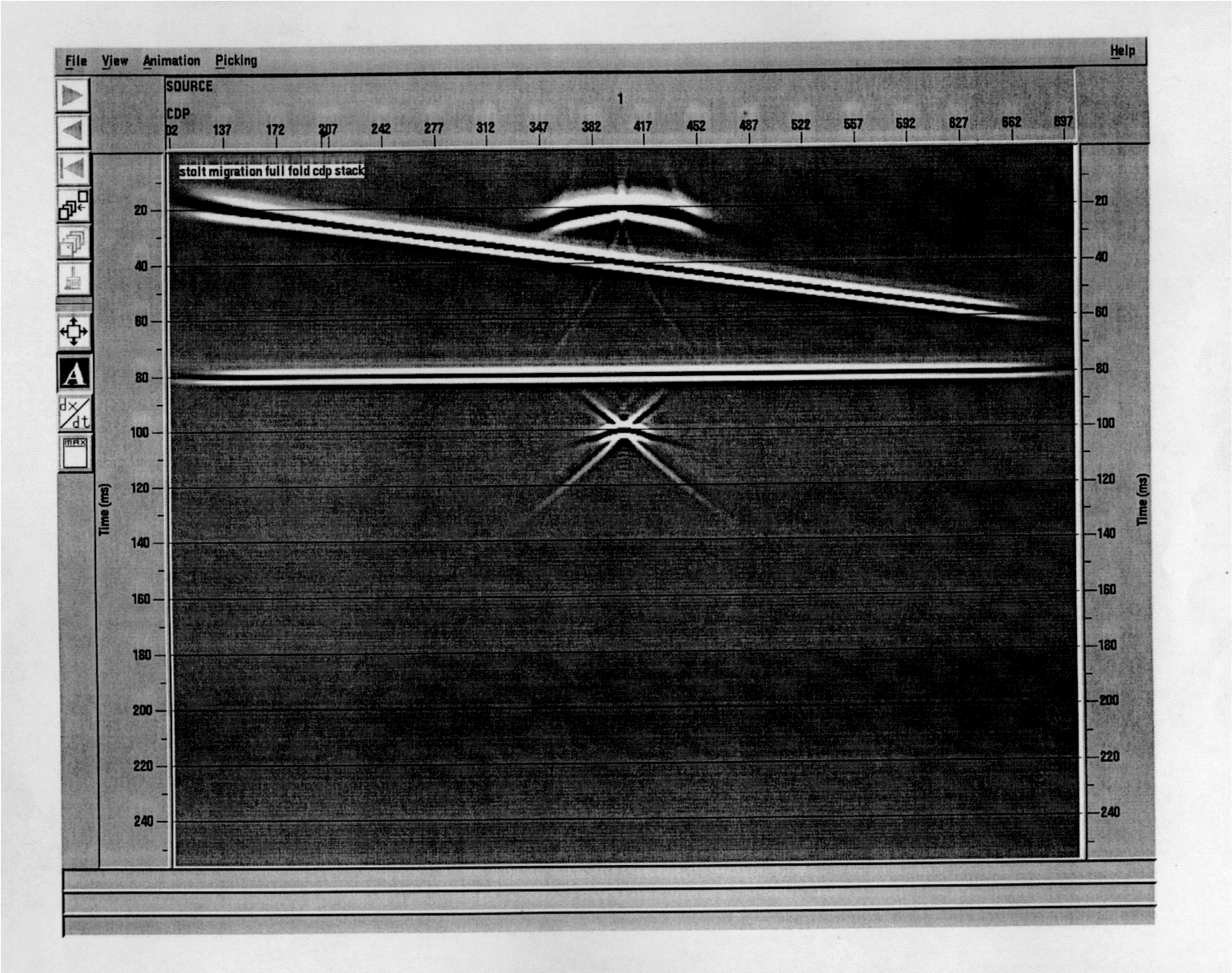
Complex structure: simplest case of diffractors

Stack with no DMO



Complex structure: simplest case of diffractors

Migrated stack
With no DMO



Complex structure: simplest case of diffractors

Stack with DMO

Complex structure: simplest case of diffractors

Migrated stack
With DMO

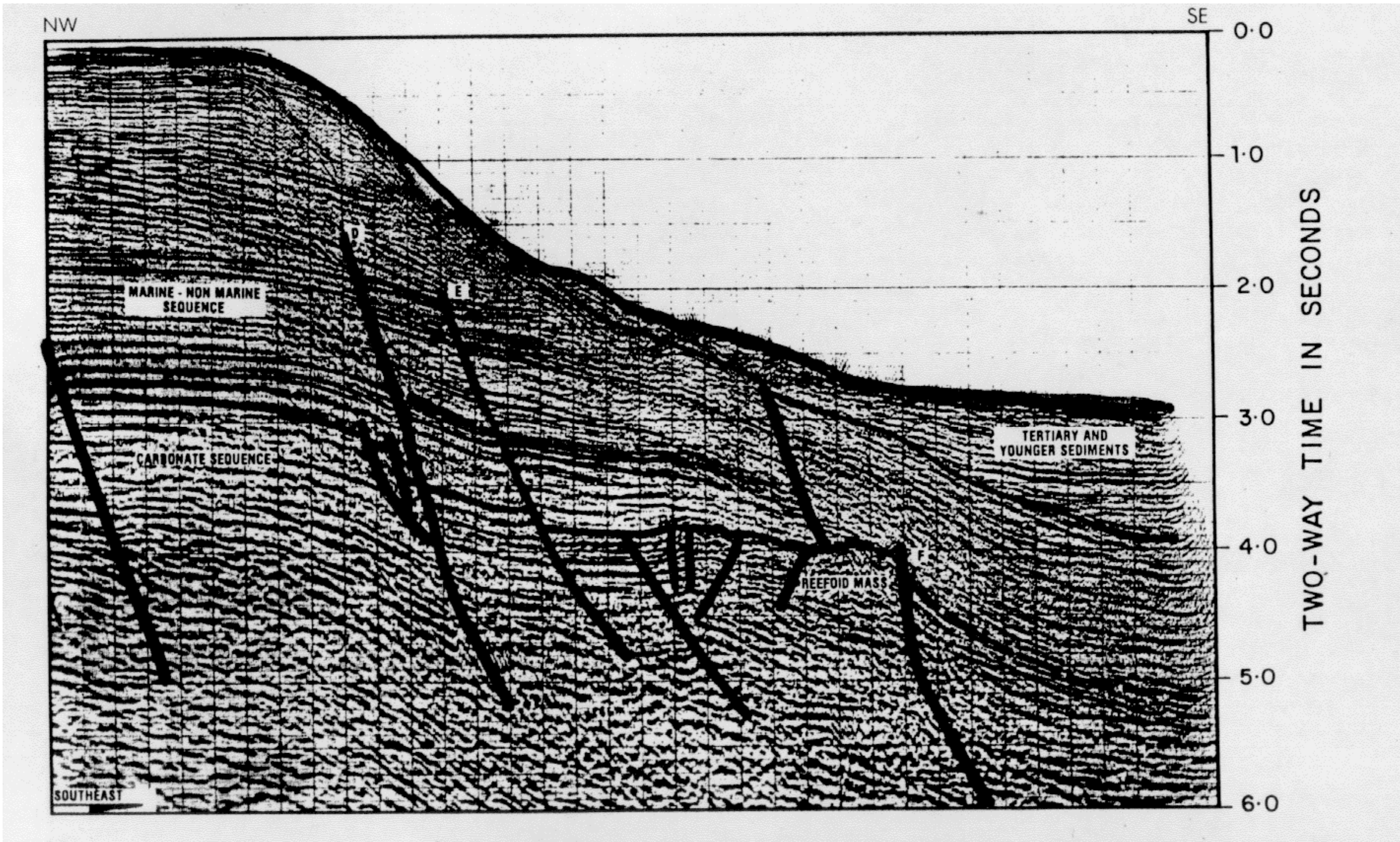
Complex structure: simplest case of diffractors

Complex case:

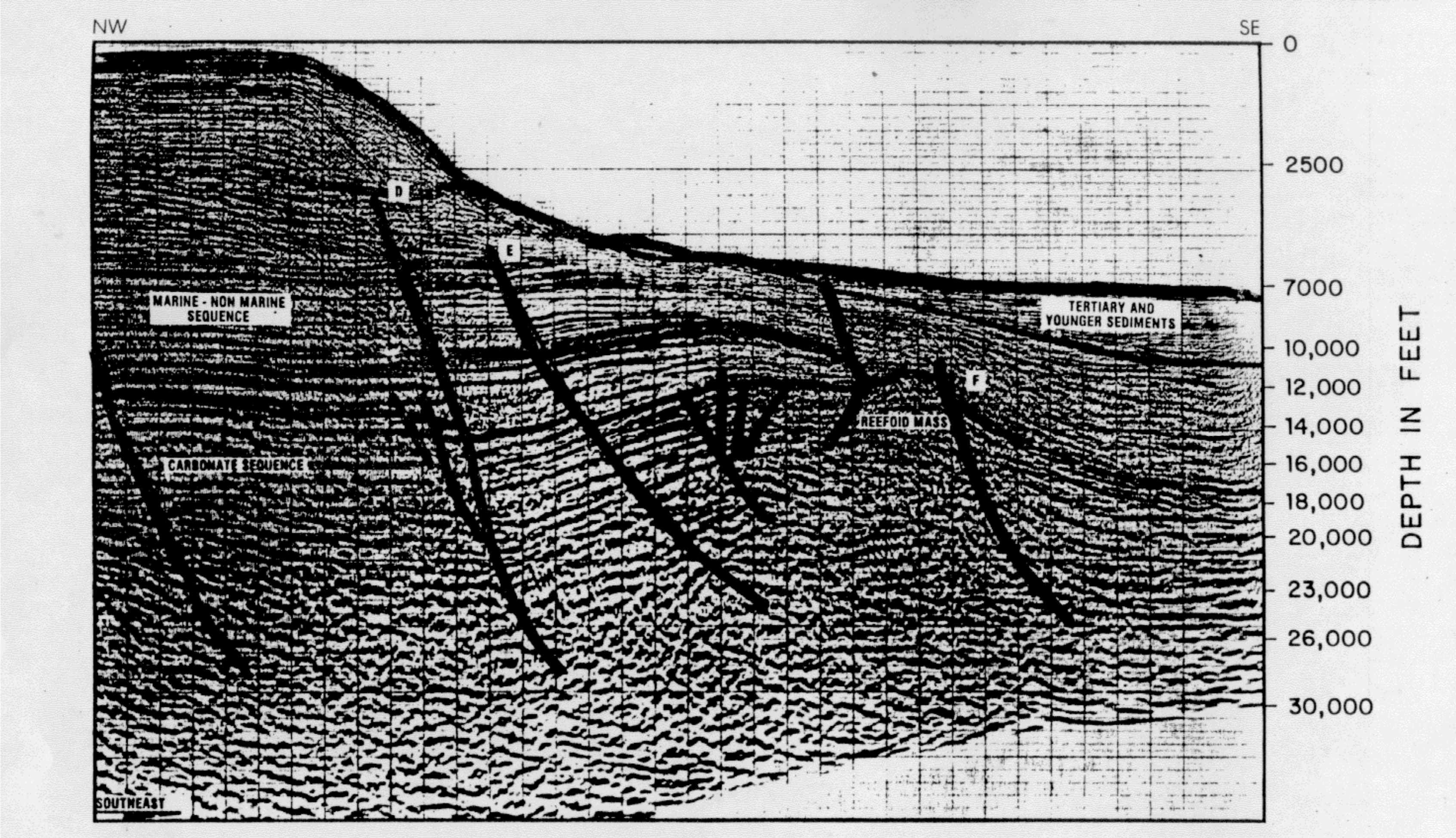
DMO = form of pre-stack time migration necessary

(only root-mean-square-velocity model necessary)

Large lateral velocity variations: time section



Large lateral velocity variations: depth section



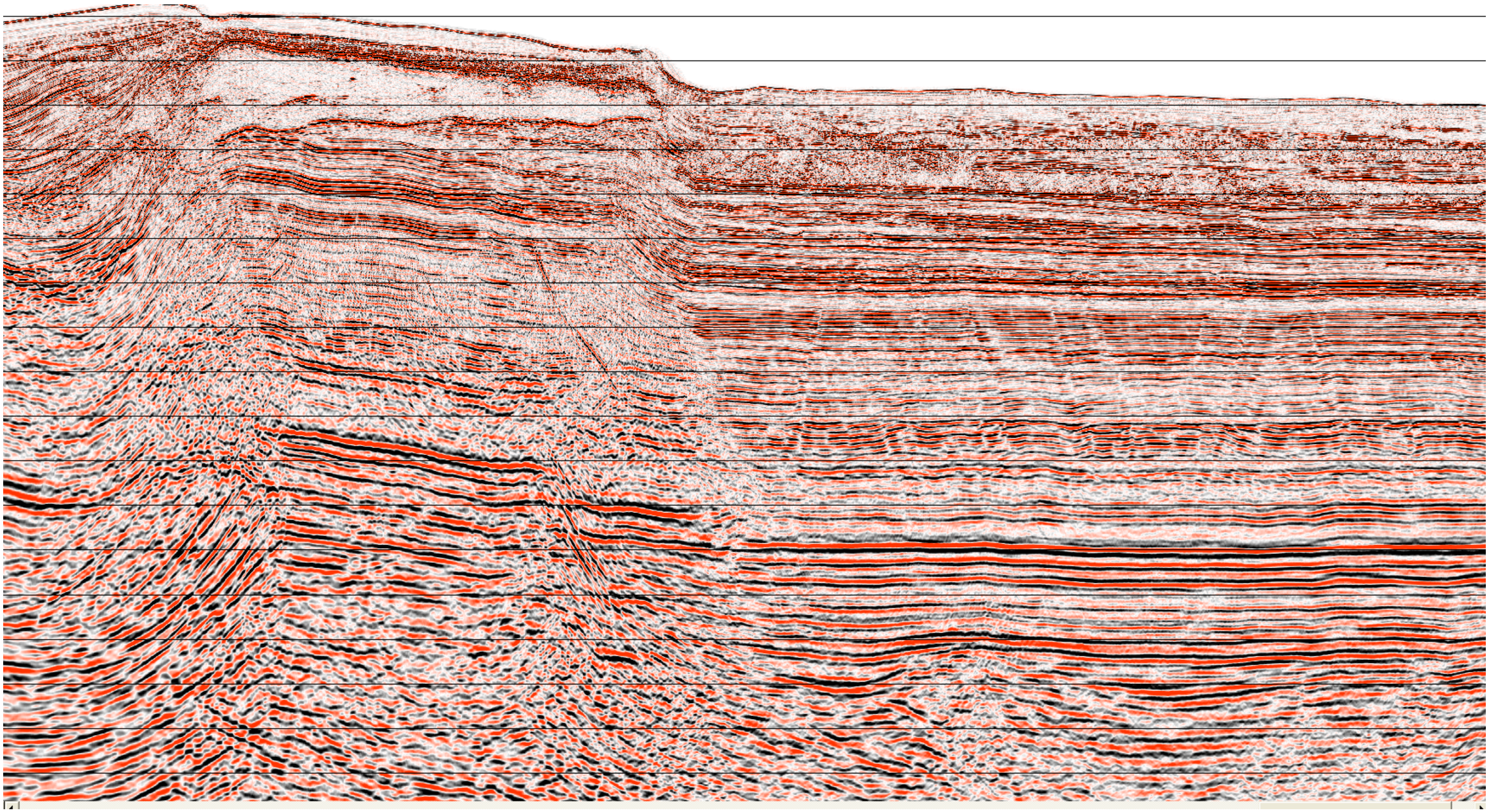
(b)

Large lateral velocity variations

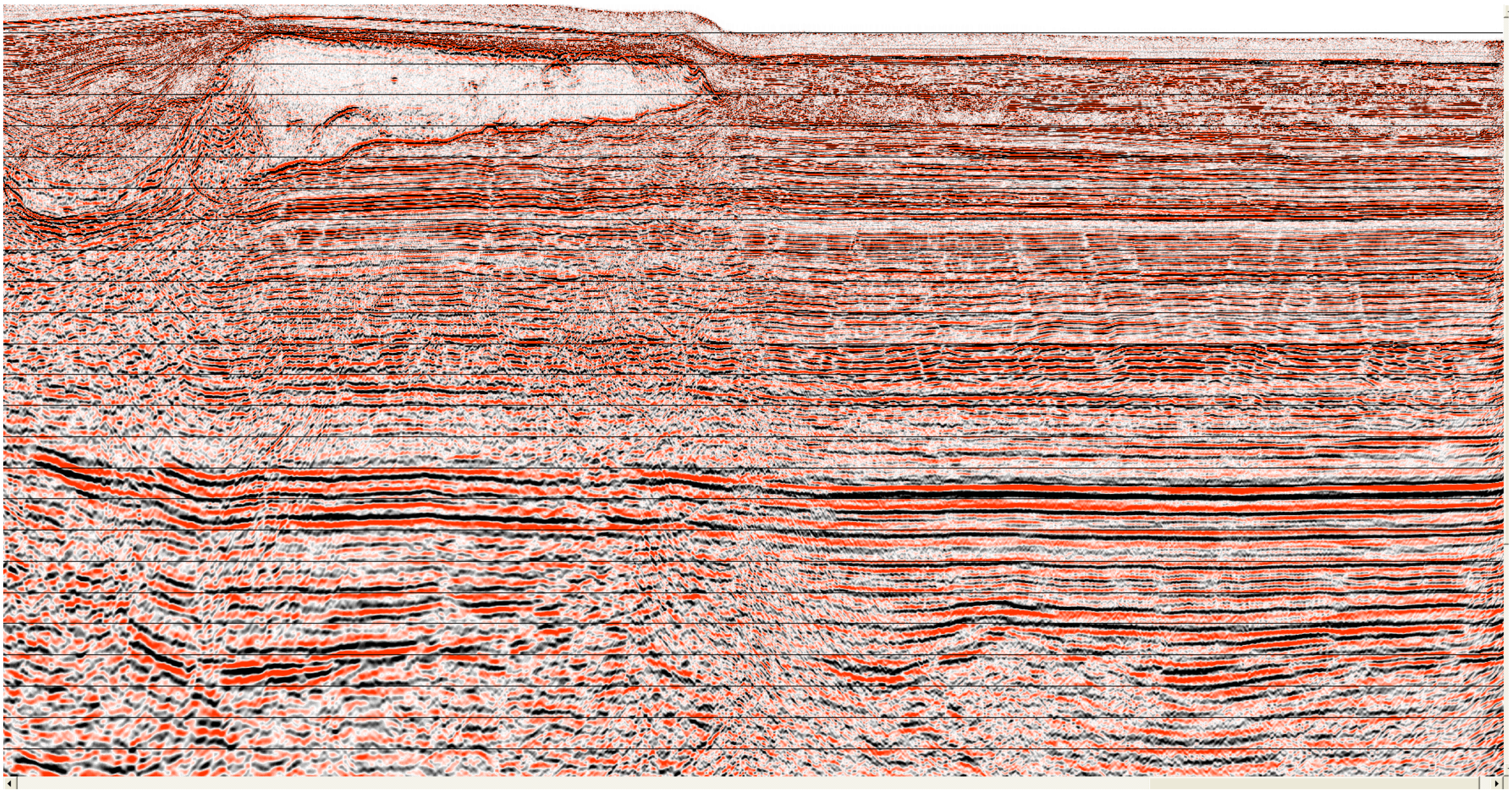
Notice **lateral shift** of faults as well

(so here time-stretching axis will not do !!!)

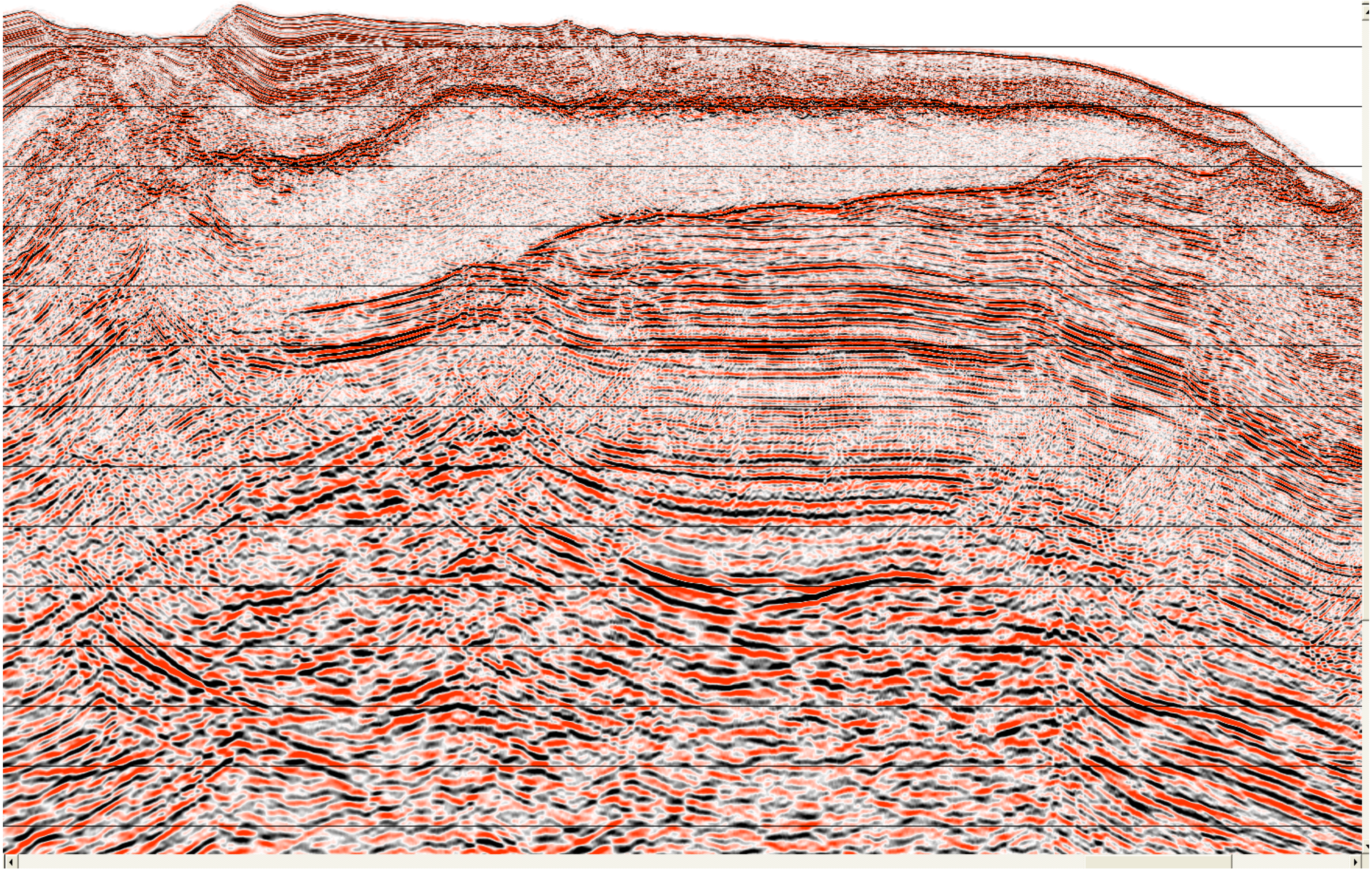
Kirchhoff Pre-stack Time Migration



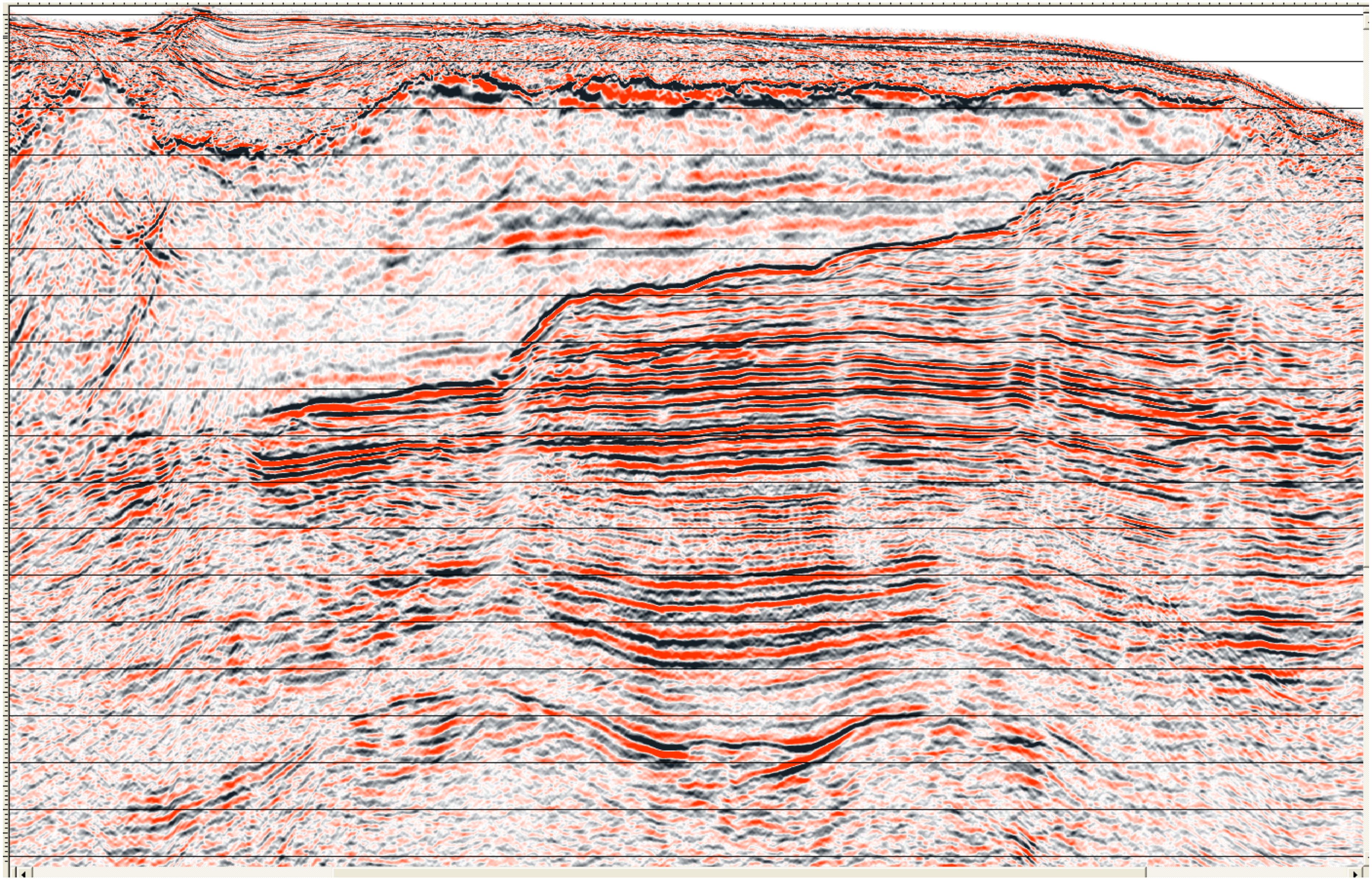
Kirchhoff Pre-stack Depth Migration



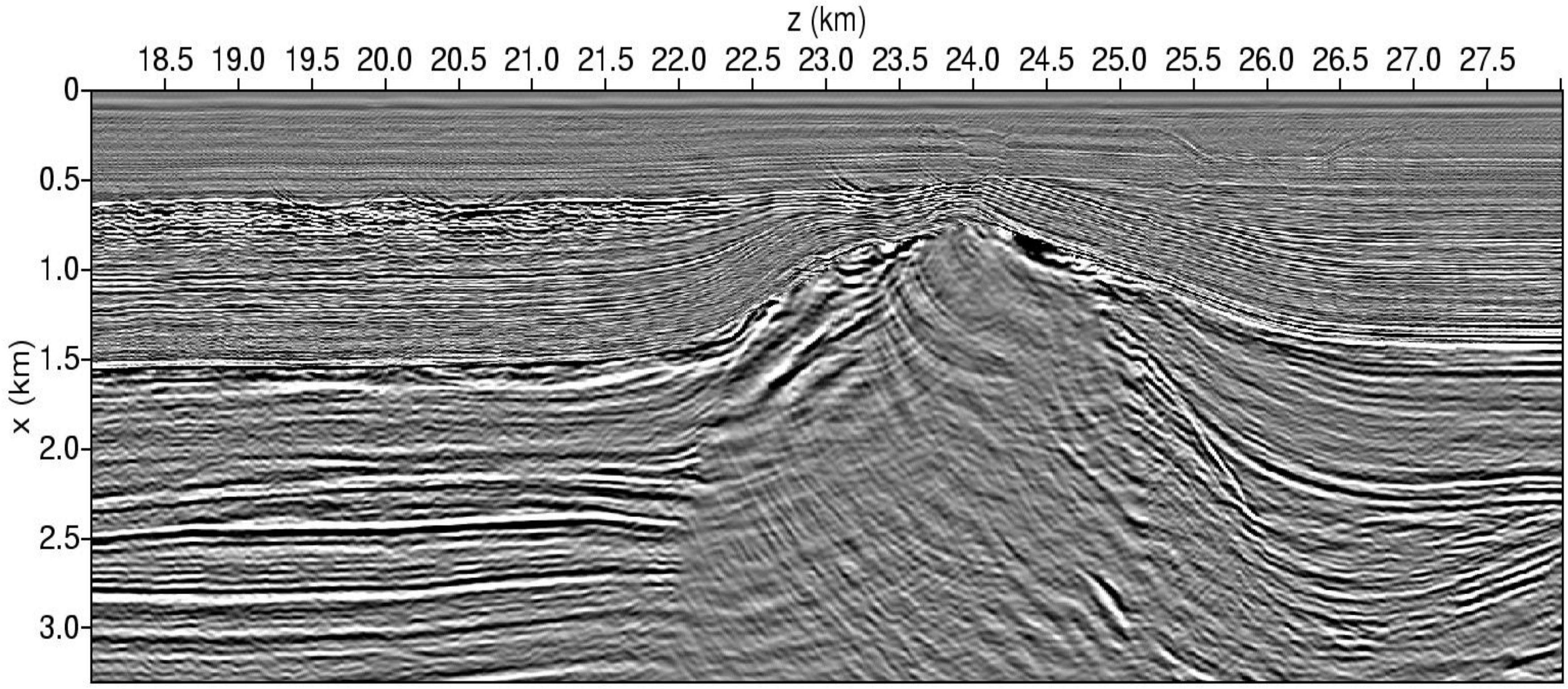
Kirchhoff Pre-stack Time Migration



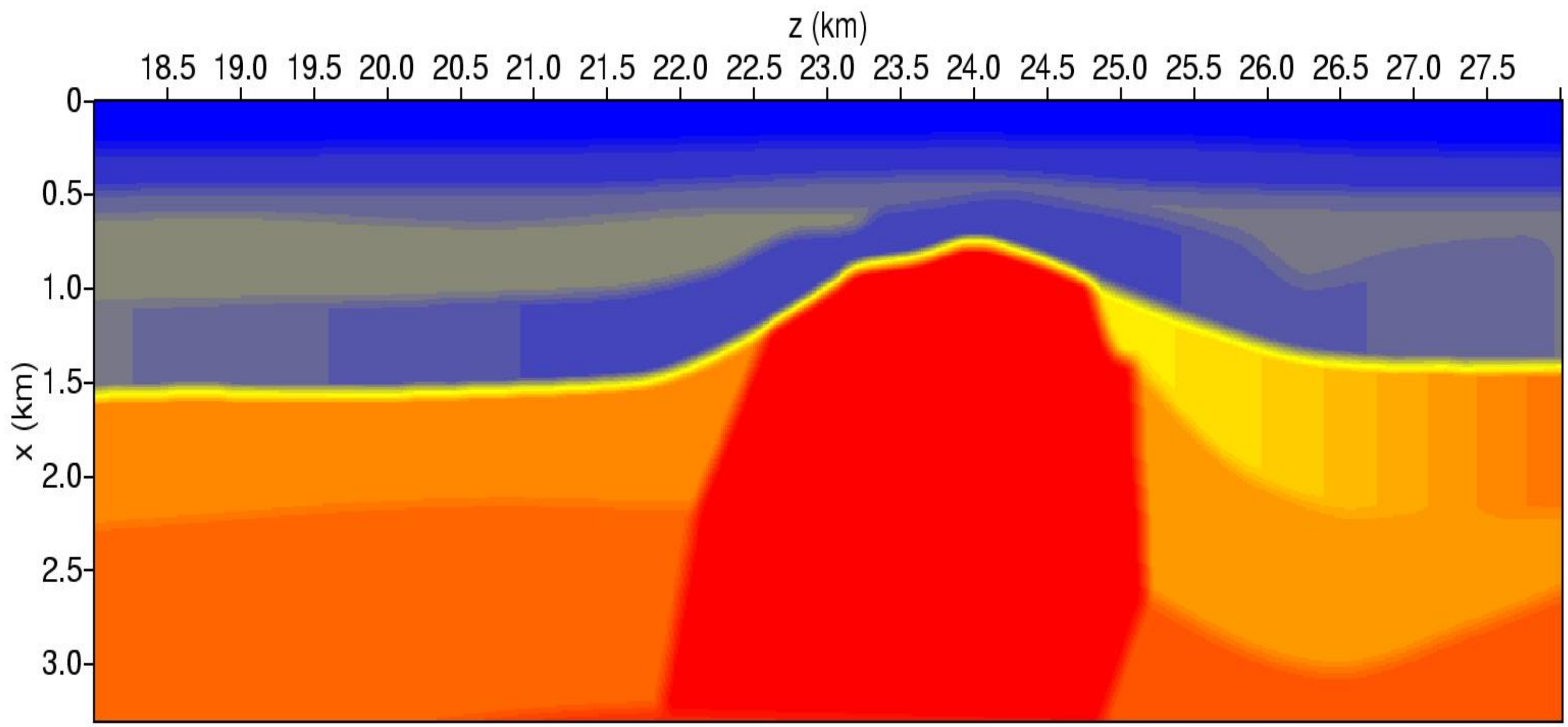
Wave Equation PSDM



Large lateral velocity variations and complex structure

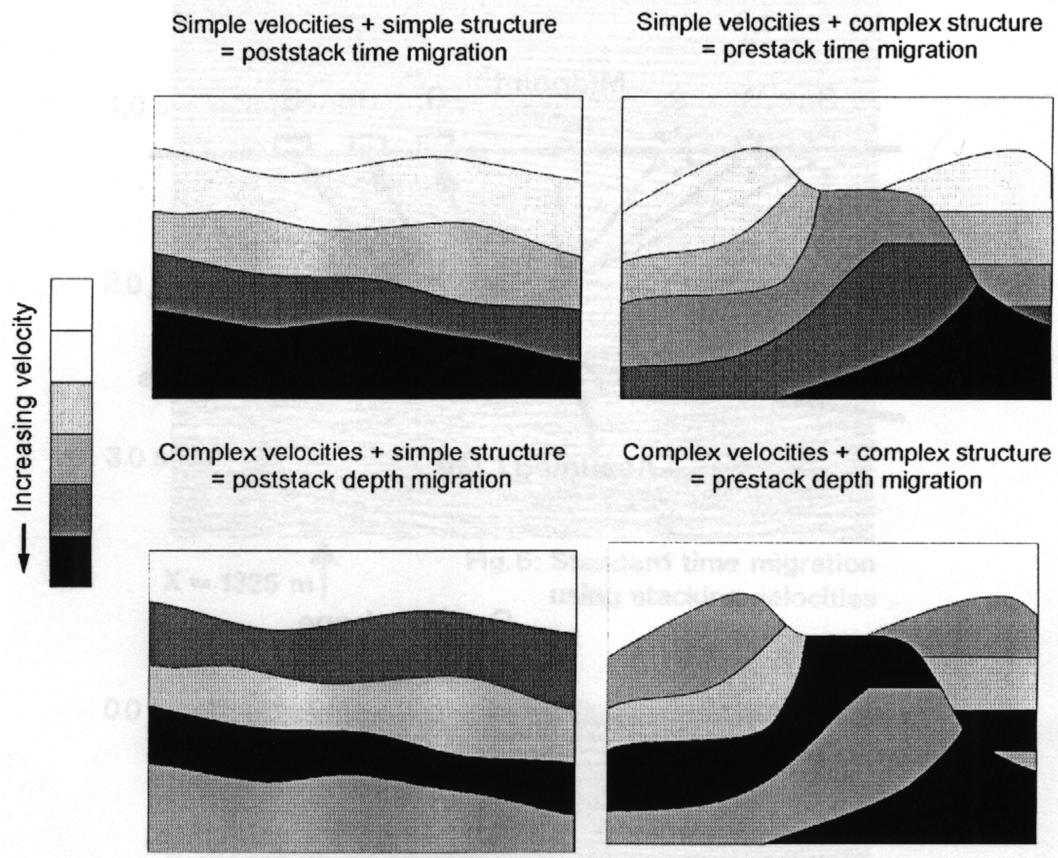


Large lateral velocity variations and complex structure



(Interval-) velocity model

Velocities/Structures and migration



Sketches showing typical subsurface situations and the recommended imaging solutions (After Farmer et al. 1993).

Strategy for seismic migration

- **Simple structure, small lateral velocity variations:**
  post-stack time migration

- **Complex structure, small lateral velocity variations:**
  pre-stack time migration (generalisation DMO)

- **Simple structure, large lateral velocity variations:**
  post-stack depth migration (pull-up effect)

- **Complex structure, large lateral velocity variations :**
  pre-stack depth migration (e.g. side of salt domes)

Migration: wave theory

Migration is:

$$(\, X \,,\, Y \,,\, T \,) \rightarrow (\, X \,,\, Y \,,\, Z \,)$$

or, better,

$$(\, X \,,\, Y \,,\, Z=0 \,,\, T \,) \rightarrow (\, X \,,\, Y \,,\, Z \,,\, T=0 \,)$$

Migration: wave theory

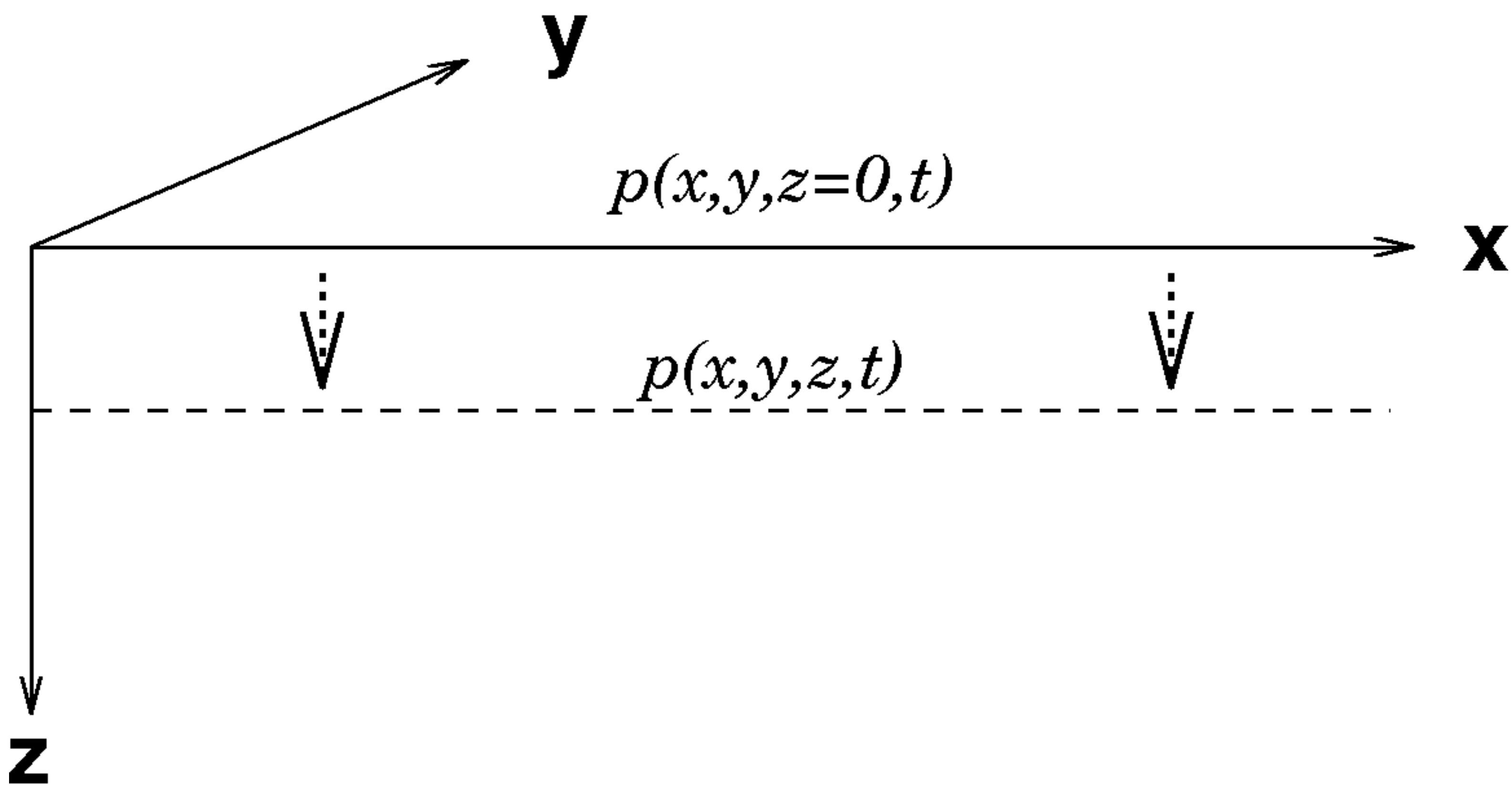
Transform measurements at $z=0$ for all t
into measurements for $t=0$ for all z !

Two-step procedure:

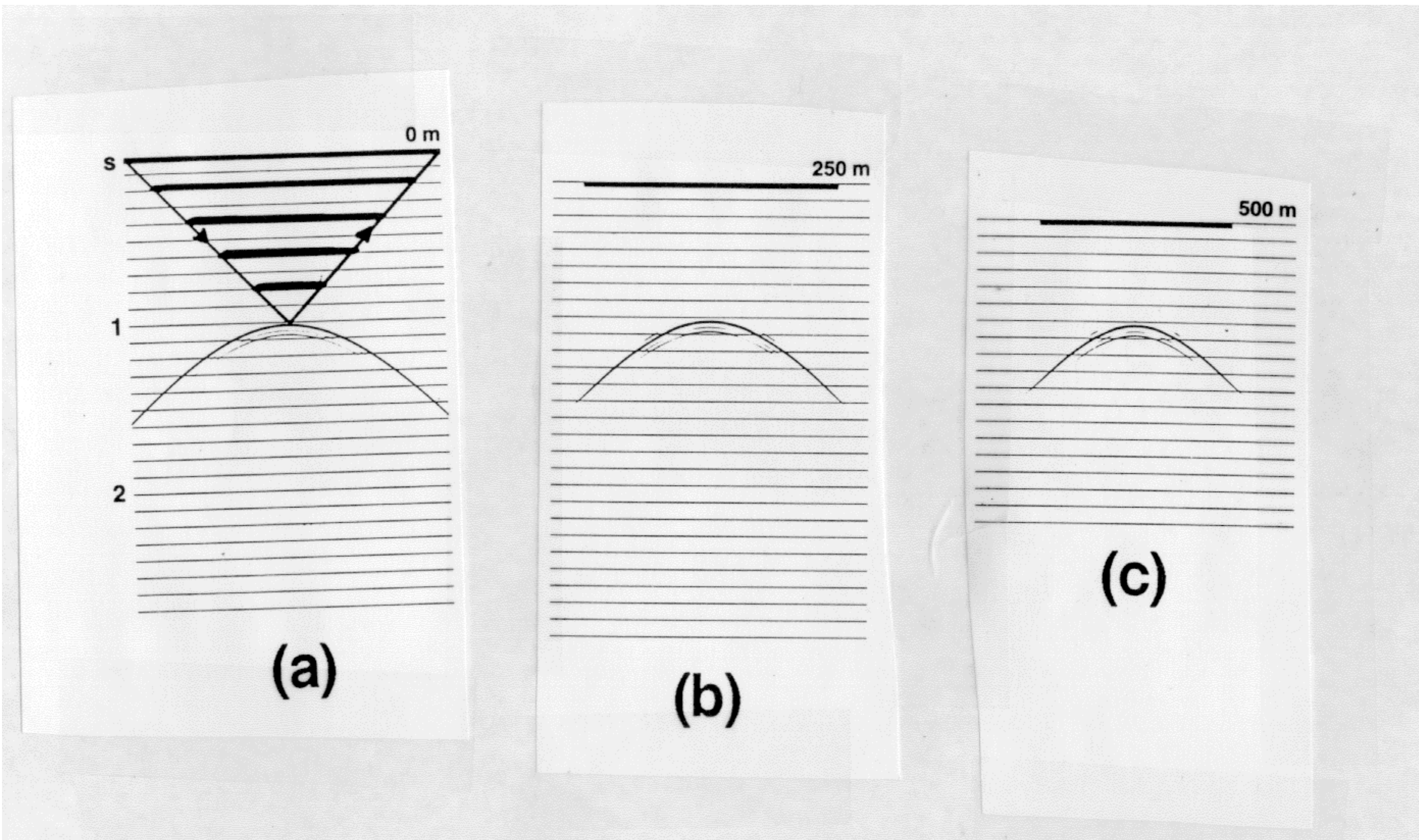
1: Extrapolation:
Bring $\boldsymbol{P(x, y, z=0, t)}$ to $\boldsymbol{P(x, y, z=z_m, t)}$

2: Imaging = Select only $t=0$:
$$\boldsymbol{P_{migr}(x, y, z=z_m, t) = P(x, y, z=z_m, t=0)}$$

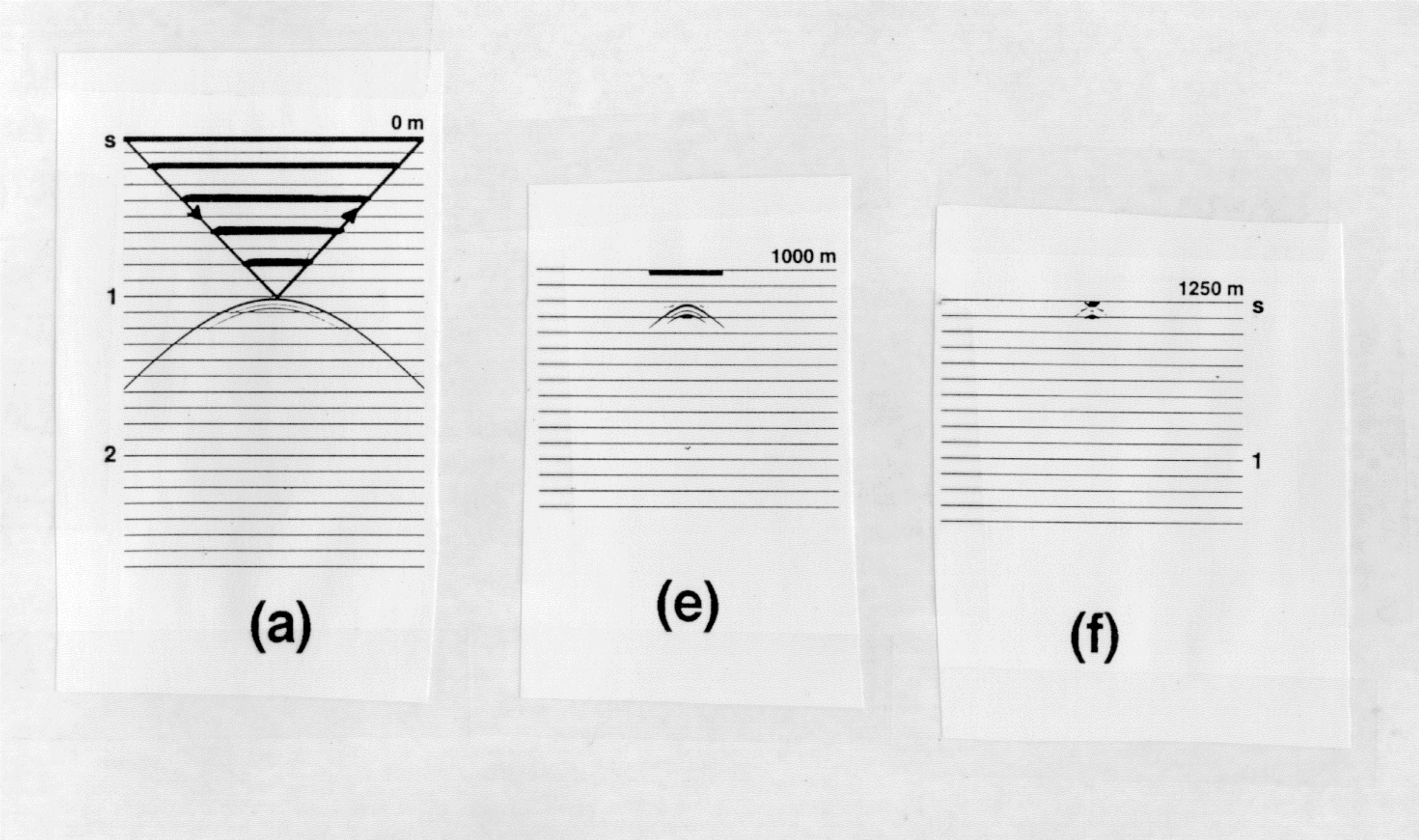
Wavefield extrapolation



Wavefield extrapolation



Wavefield extrapolation (2)



Zero-offset migration scheme

Zero-offset migration can be applied by:

• Consider zero-offset data as exploding reflector measurements in medium with half the true velocity

• Extrapolating surface data into subsurface

• At $t=0$, the imaged reflector should appear at correct depth
(Imaging condition)

Often for geological interpretation, the output is calculated as a function of time.

Ideal migration when velocity model is known

Pre-stack Depth Migration:

- **Inverse wavefield extrapolation receivers into medium**
- **Forward wavefield extrapolation source into medium**
- **Correlate two resulting wavefield**
- **Extract *t=0* component**