Marianne Karplus

Assistant Professor
2015-present
Univ. of Texas at El Paso

History

Dartmouth College
B.A. Earth Science & Math, 2004

2004-2006: Working for small geology software company

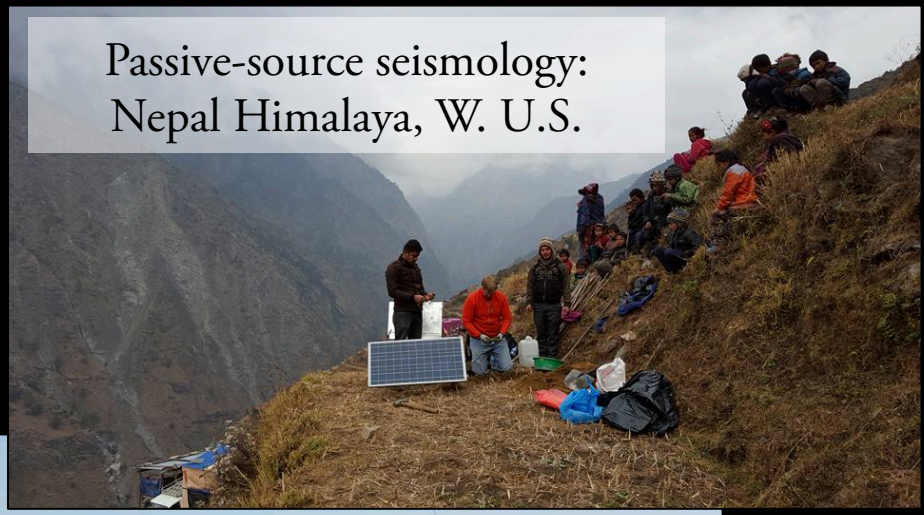
Stanford Univ.
Ph.D. Geophysics
2006-2012

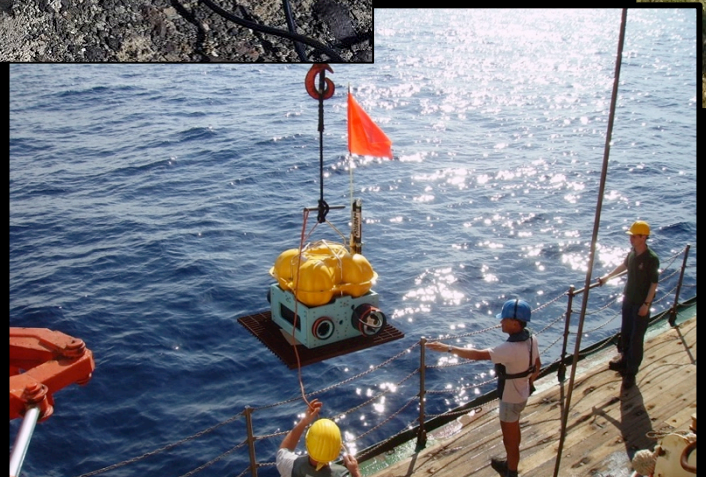
Univ. of Southampton, UK
Postdoc 2012-2014

Research projects…

Active-source seismology: Tibet, Sumatra Subduction Zone, W. U.S.

Passive-source seismology: Nepal Himalaya, W. U.S.





Active-source seismology

Marianne Karplus

U.S. Array short course

August 2016

Active-source seismology: key concepts

Overview: Acquisition & Processing
Physics: Rock physics, velocities, amplitudes, reflection / refraction raypaths
Mathematics: Time & frequency domains, Fourier transforms, amplitude & phase spectra, digital filtering, convolution, correlation

Sources & Receivers: dynamite, vibroseis, airguns; geophones & hydrophones

Arrays: surface sampling, surface ghosts, frequency effects CMP (common-midpoint) method, Stacking charts, Survey design

Velocity: measuring interval, rms, stacking, NMO & apparent velocities
Statics: refraction statics, automatic statics

Migration and DMO: migration equation; effects on stack data; wavefront, Kirchhoff, f-k, & finite-difference methods; time vs. depth migration

VSP (vertical seismic profiling), *3D seismics, S-waves, AVO* (amplitude-vs-offset)

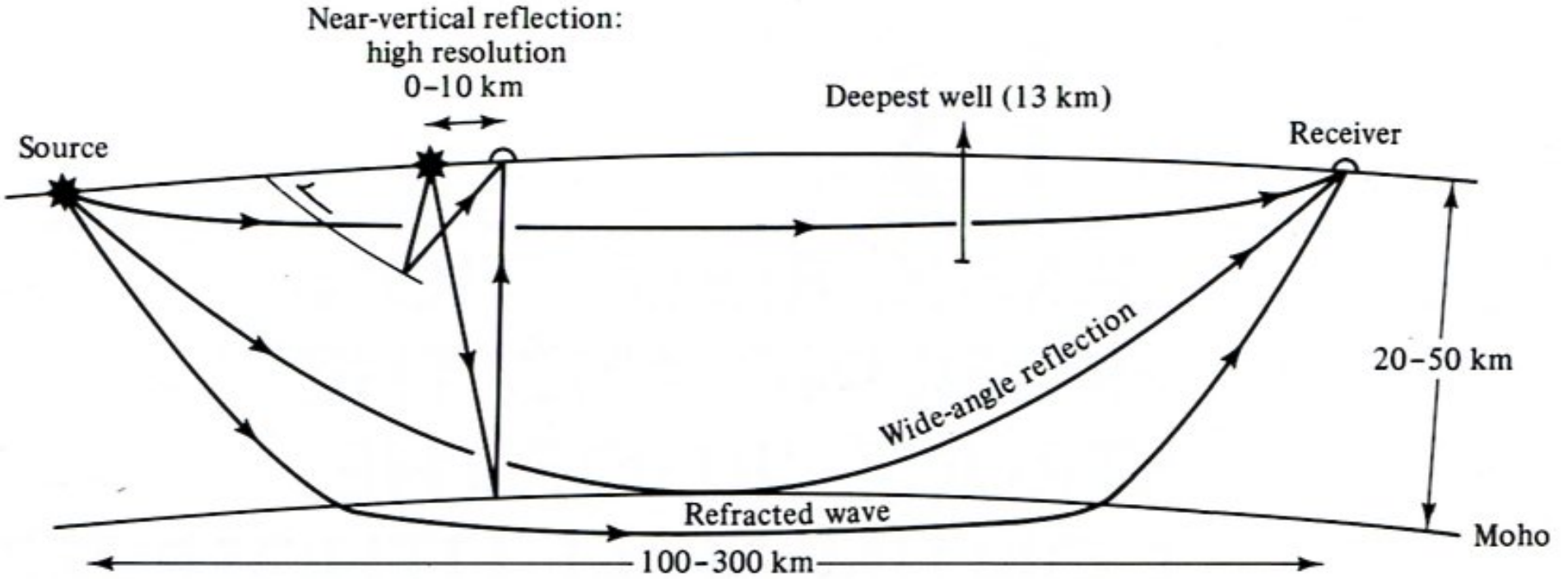
Historical development of active-source

Year	Acquisition	Processing
1849	First controlled-source seismic experiment (Robert Mallet exploded a barrel of gunpowder near Dublin)	
1919	First reflection experiment (quarry near DC, 4/12/1919, Clarence Karcher)	
1925	First oil discovered by refraction (Orchard Dome, SW of Houston using fan-shooting to spot fast velocities through shallow salt domes)	
1928	First oil discovered by reflection (Maud field, Oklahoma)	
1930s		Automatic gain control (AGC)
1940s	First marine profiles	
1950s	Analog magnetic recording	Common midpoint method (CMP) Trace stacking
1960s	Digital recording Vibroseis source (on land) Airgun source (at sea)	Deconvolution

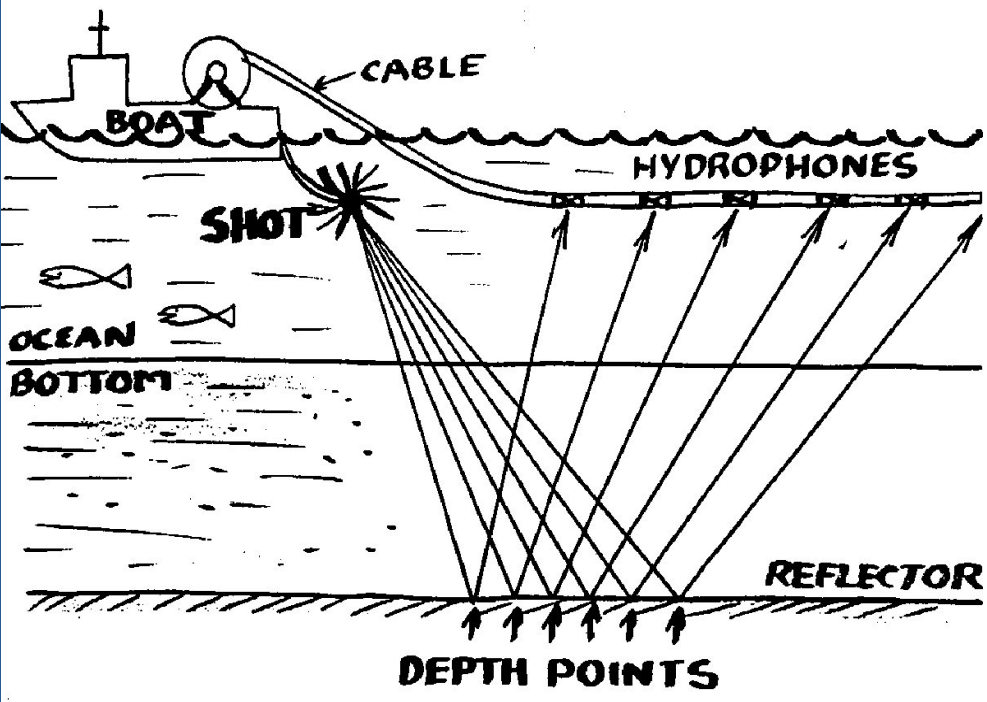
Reflection (near-vertical; offset ≤ penetration)

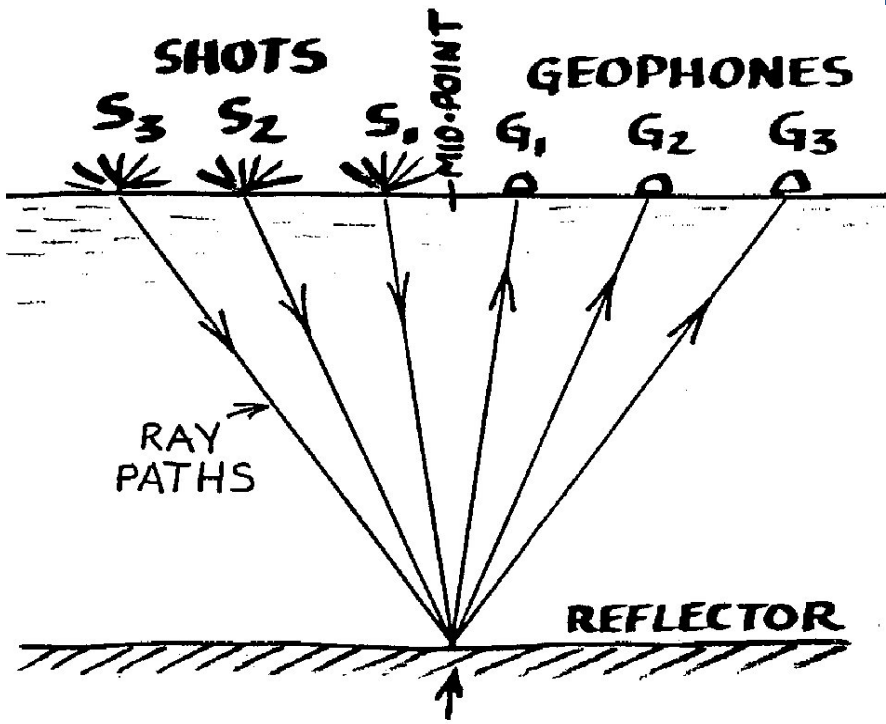
vs.

Refraction (wide-angle; penetration ≤offset)



Refraction/wide-angle reflection: rays average crustal properties



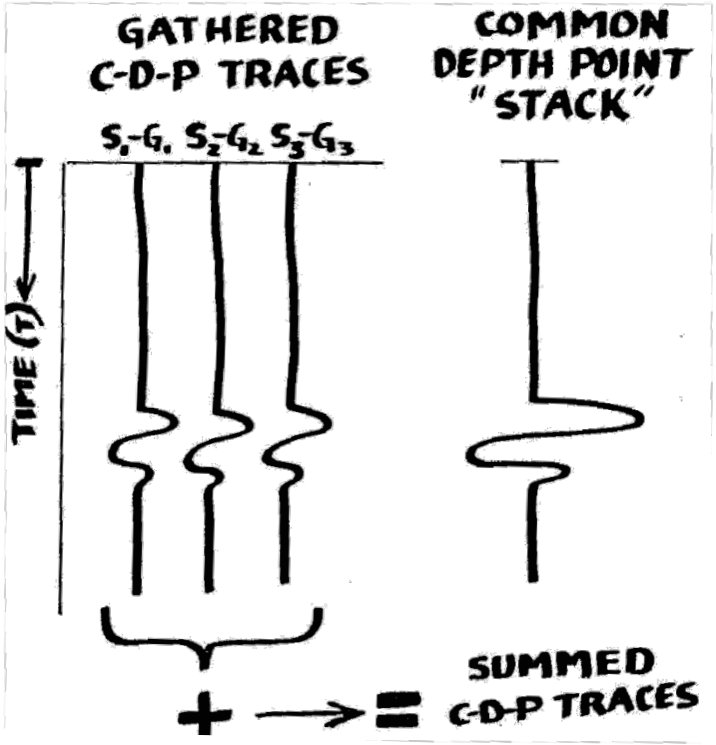


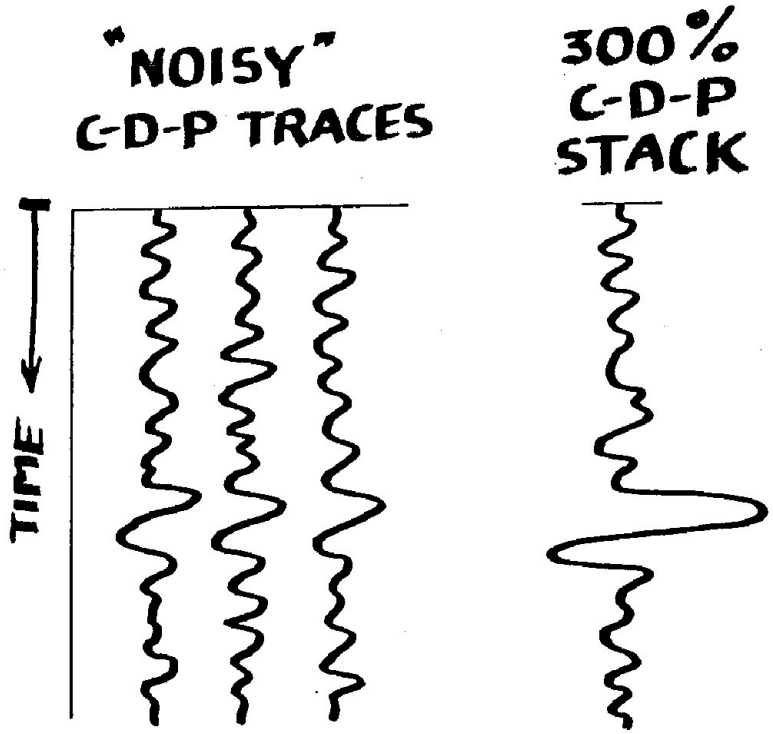
Single shot geometry:

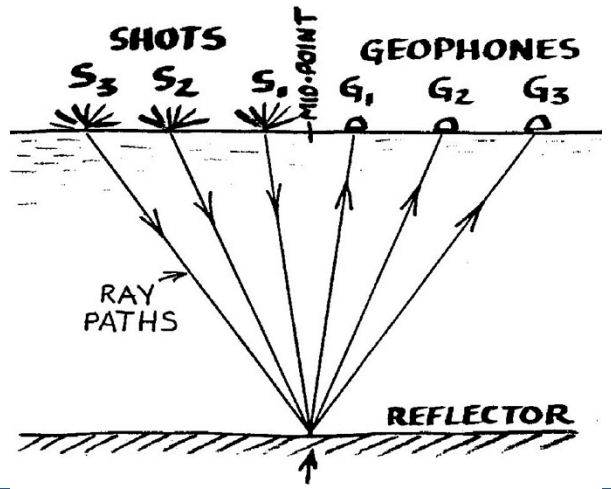
all traces share a common source; the ensemble of recordings (traces) is a "common-source gather"

CMP geometry:

all traces share a common surface source-receiver mid-point; for 1D geology, all traces share a common depth point (CDP)







summing 3 traces provides a "stacking fold" of 3

Trace stacking enhances signal,
and reduces noise

Sources: hammer on aluminum plate

Xia, 2006

Sources: Betsy seis gun

Sources: accelerated weight drop

Sources: vibroseis

Sources: explosions

IRIS active seismic source facility

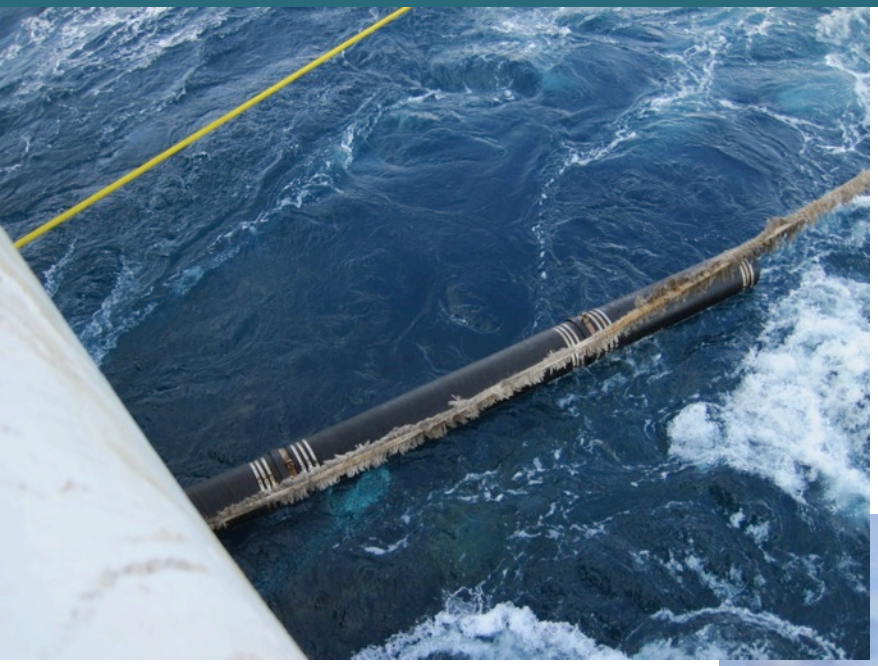
- Contact: Steve Harder at UTEP (harder@utep.edu)
- Resources, training opportunities, support for experiments
- UTEP ENAM team (minus Steve Harder):

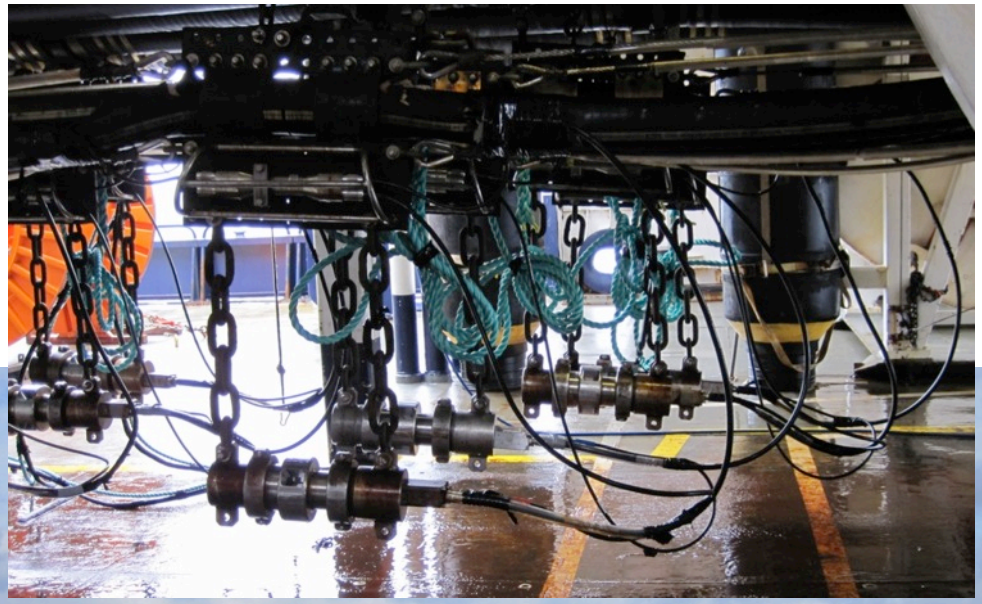
IRIS PASSCAL active-source equipment

- ~1500 Texans – 1 component (includes ~370 UTEP Texans)
- L28 and L22 short period geophones
- 14+ Geodes – 24 channels (1-3 component)
- 3 Stratavisors – 60 channels
- 63 (?) Fairfield 3C 5-Hz nodes

- 1 PEG-40 weight drop

Air gun sources and streamers



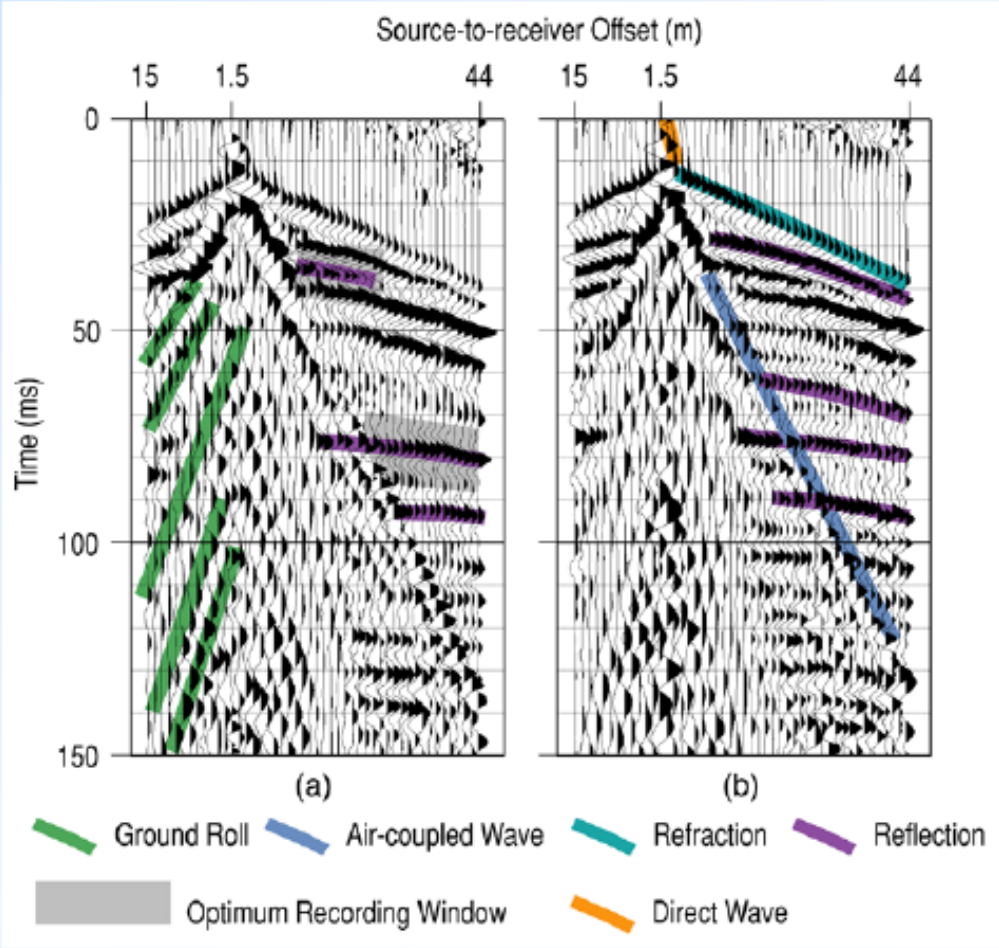


Ocean bottom seismometers (OBSIP)

Marcus G. Langseth seismic ship

Seismic wavefield: interpreting shot gathers

- Compressional and Shear
  - Body Waves
    - direct
    - refracted
    - reflected
    - diffracted
  - Surface Waves
    - Rayleigh
    - Love
- Air-Coupled Waves



Adapted from Lee Liberty

Research vignette I: 500-m shallow seismic line, NM


West El Paso
survey location:
500-m line
1071
1043
1058
1011
Sunland Park
Mt. Cristo Rey
© 2015 Google
© 2015 INEGI
Image © 2015 DigitalGlobe
Anapra
Mexico
1750 m
Google earth
Tour Guide
1991
lat 31.789268° lon -106.564394° elev 1160 m eye alt 9.18 km


1098
1093
1089
1087
1083
1081
1077
1075
1071
1067
1063
1064
1056
1053
1051
1046
1043
1042
1035
1030
1026
1022
1018
1014
1012
1011
1004
1002
1001
andesite outcrop
Rio Grande riverbed
© 2015 Google
© 2015 INEGI
111 m
Google earth
Tour Guide
1991
Imagery Date: 5/2/2014 lat 31.813704° lon -106.585699° elev 1142 m eye alt 1.65 km

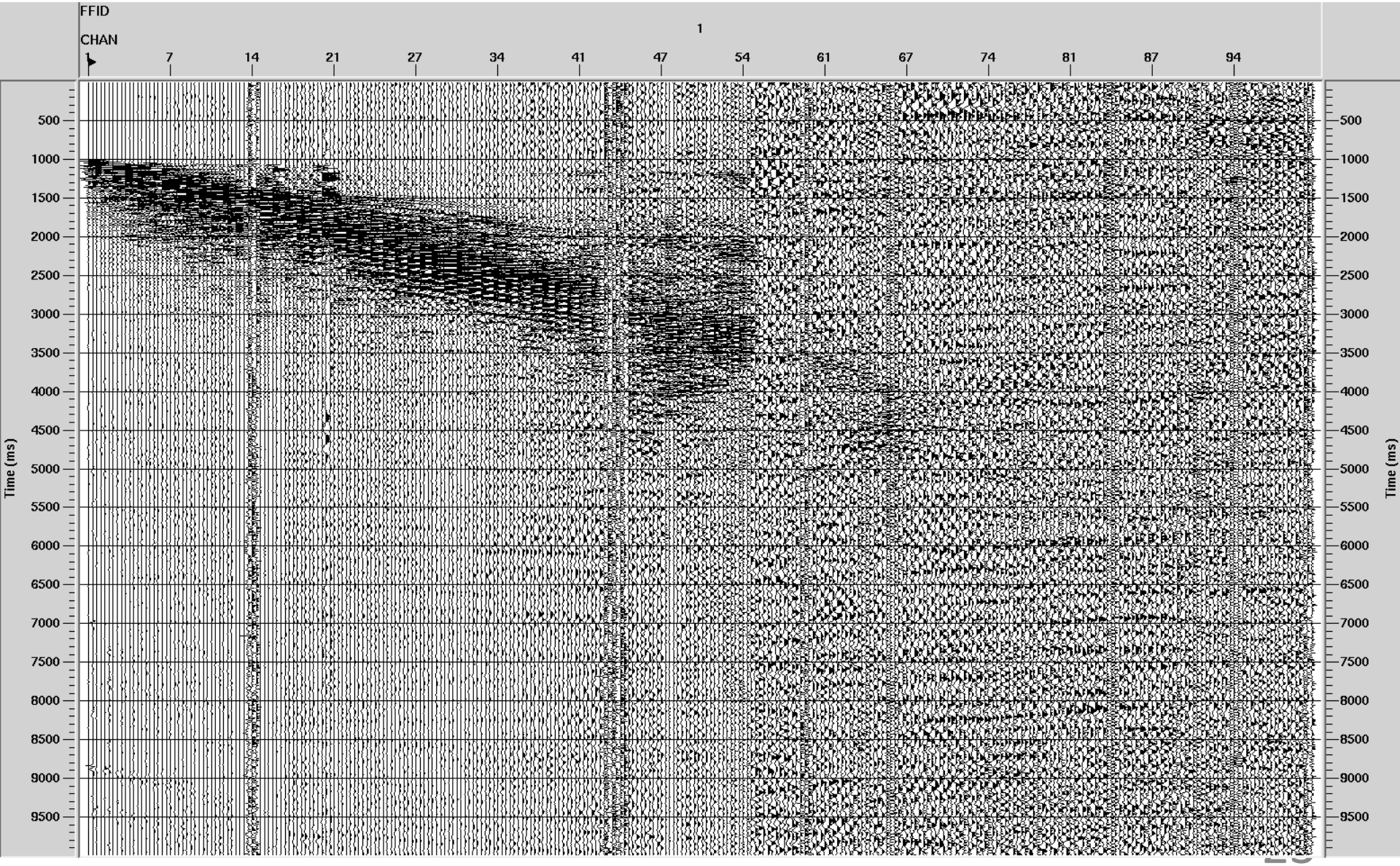
Active-source survey geometry

- 500 m long line
- Shots: Betsy seis gun: 5-10 m spacing
- Reftek Texans & 4.5 Hz geophones: 5 m spacing (100 1-C stations)
- Fairfield nodes: 10 m spacing (47 3-C stations)

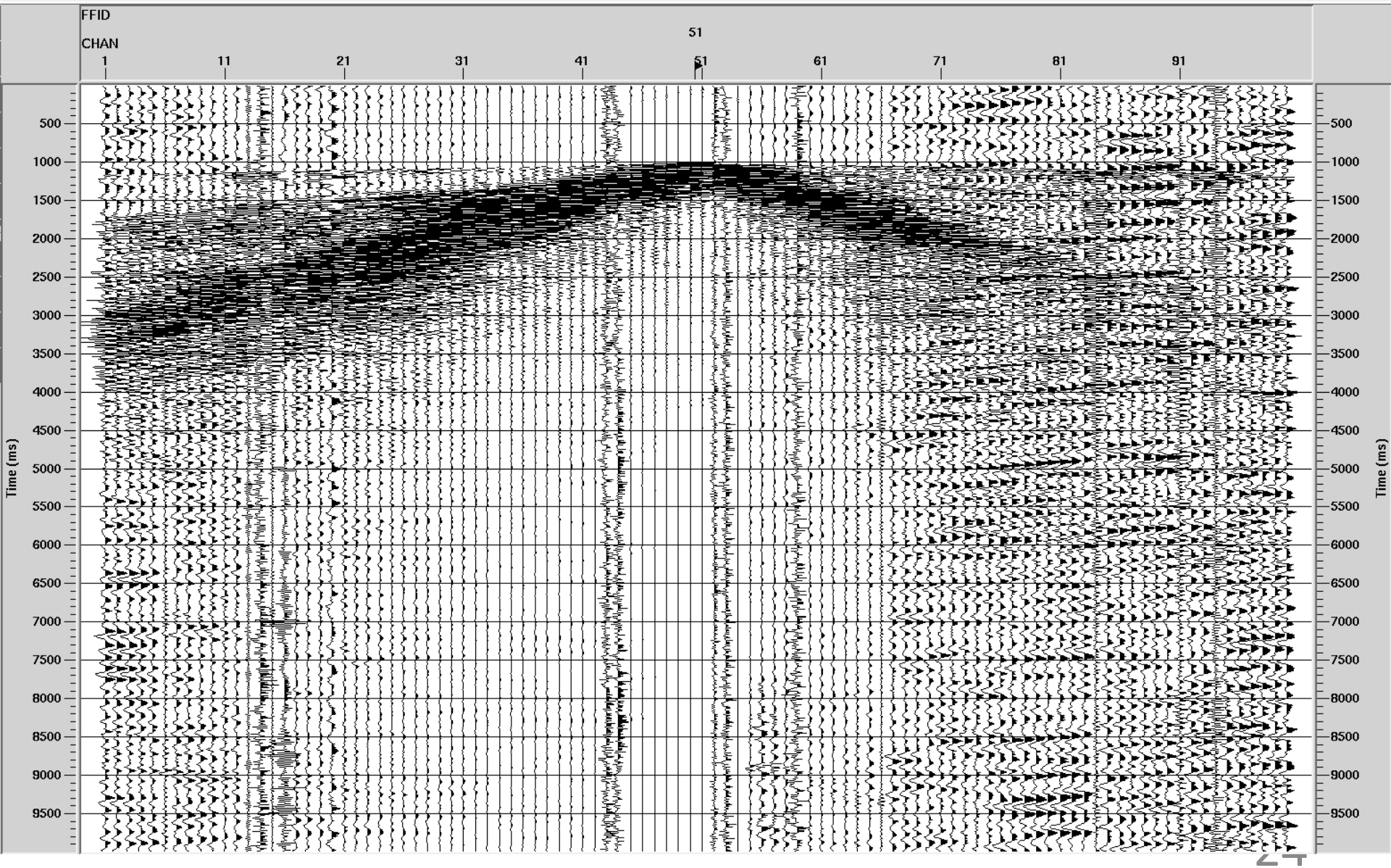
Goals of shallow seismic survey

- Determine subsurface lithologies for top ~100 m based on velocity
- Determine depth of water table
- Determine depth extents and geometry of andesite
- Look at contact relationships between andesite and surrounding lithologies/ sediments
- Build on existing subsurface models of this region from gravity, electromagnetics, ground penetrating radar
- Test the Fairfield 5-Hz nodes compared to the Reftek Texans with a 4.5 Hz geophone

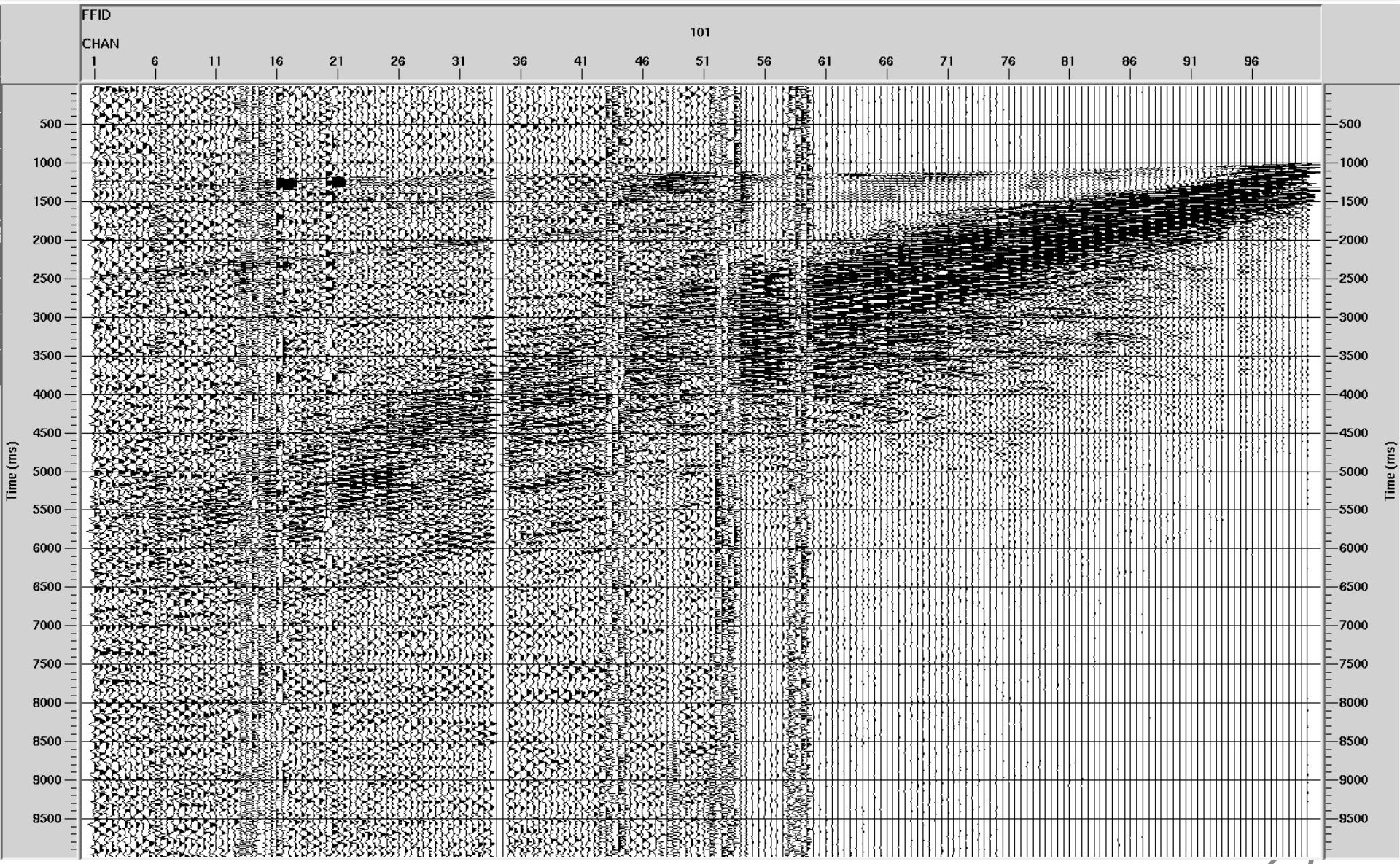
Texan data: shotpoint 1 (south end)



Texan data: shotpoint 41



Texan data: shotpoint 68 (north end)



Initial results: 500-m shallow seismic line

- Data quality of Fairfield nodes appears similar to that of Reftek Texans

- Refractions and reflections present in data – processing in progress

Research vignette II: 270-km deep seismic line, Tibet

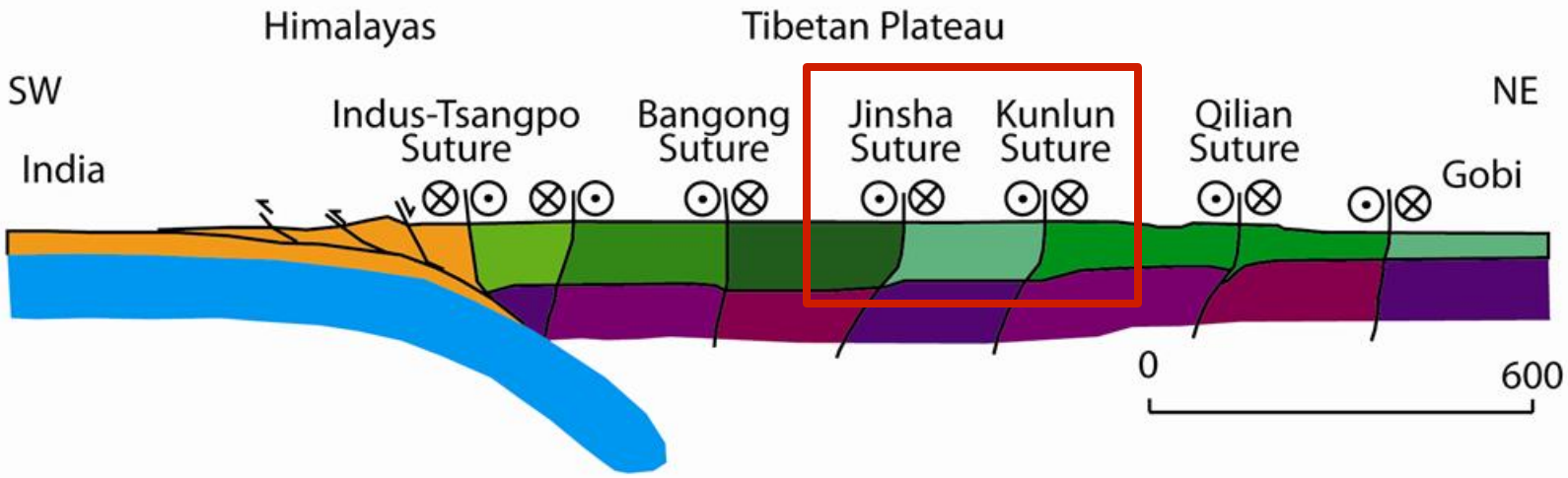
Key tectonic questions

Aim: Understand large-scale lithospheric structure & tectonics

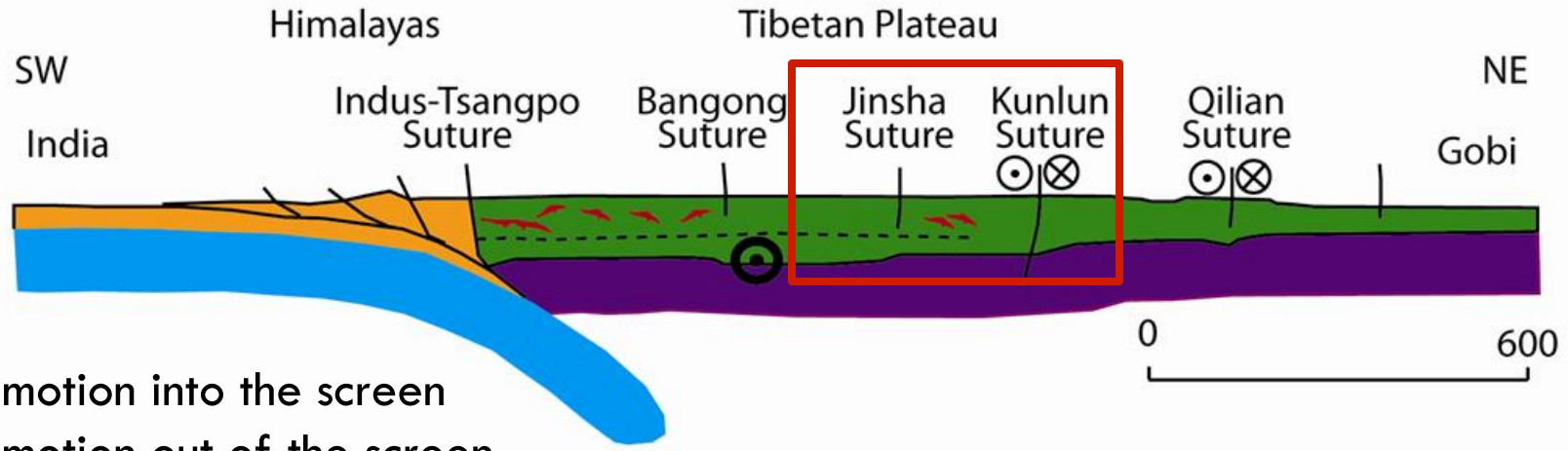
- What is the basic crustal and upper mantle structure?
- How does lithospheric structure and composition relate to rheology?
- How does lithospheric structure and composition relate to deformation and faulting?
- What are the seismic and tsunami hazards?
- What is the resource potential?

Suggested tectonic cross sections across Tibet

Terrane motion along strike-slip faults (e.g., Tapponnier et al., 2001)



Crustal flow outwards from the plateau (e.g., Clark & Royden, 2000)

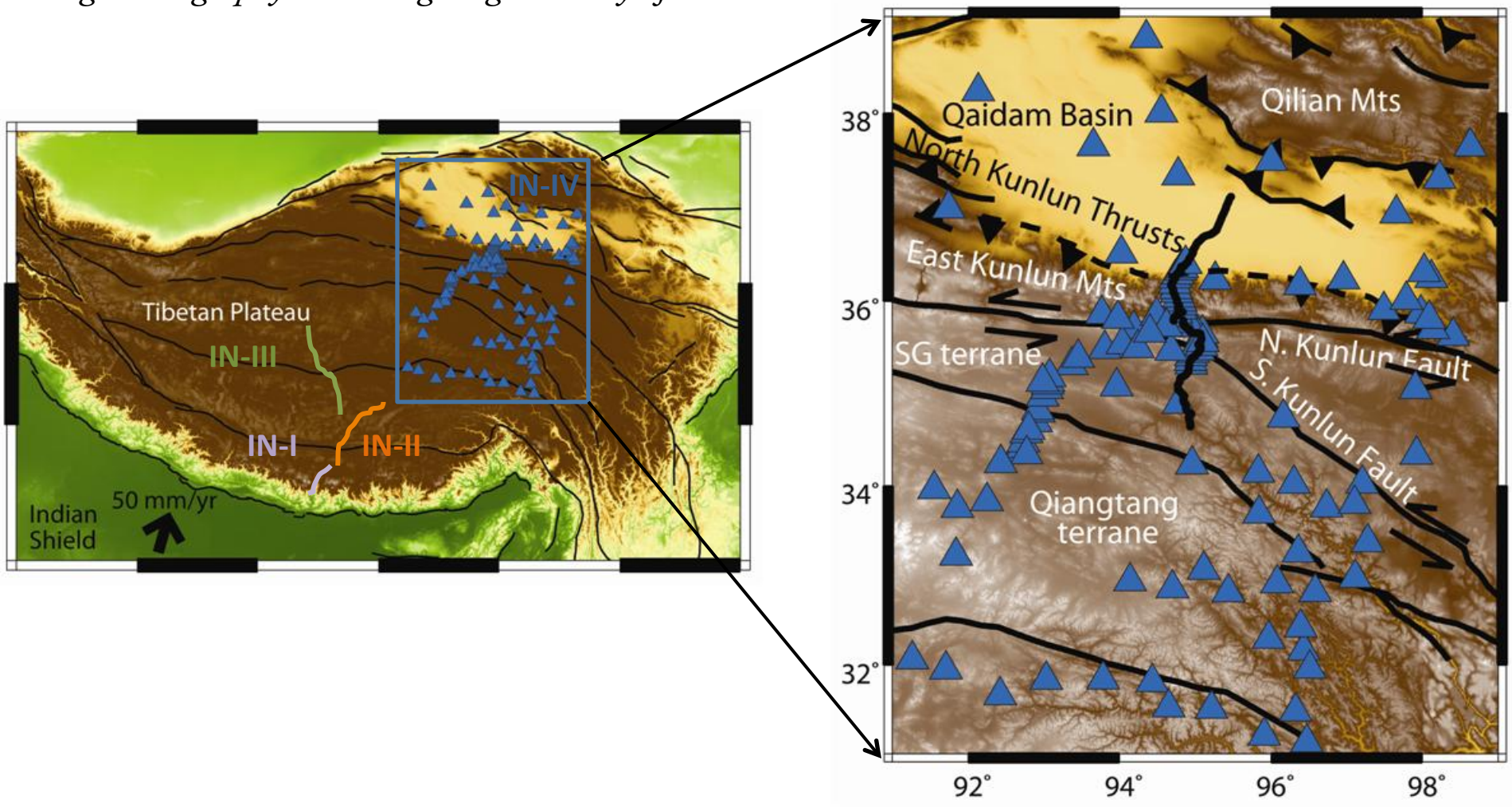


⊗ = motion into the screen

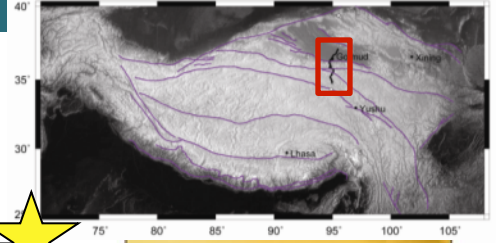
⊙ = motion out of the screen

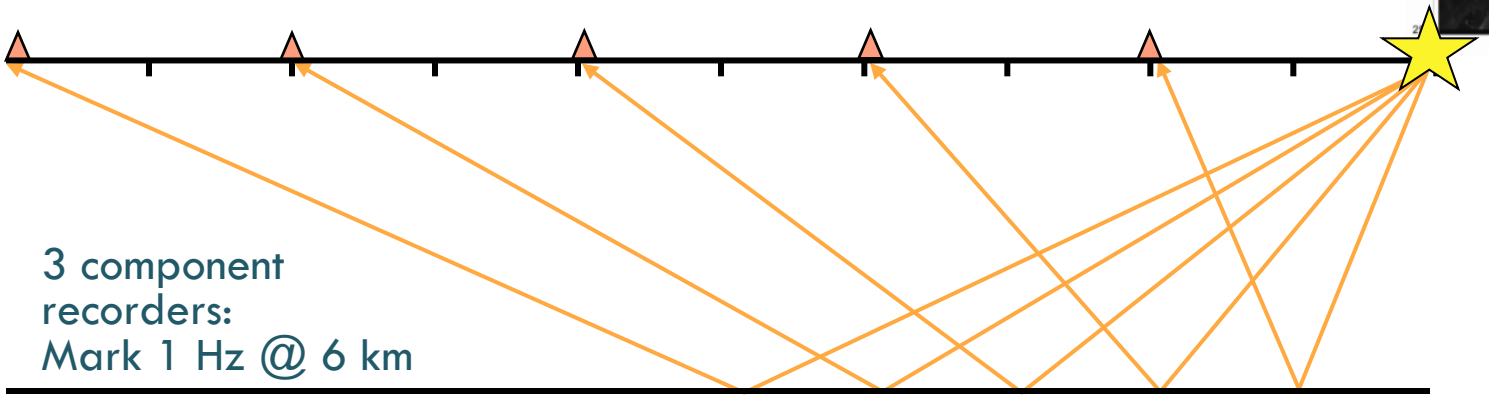
INDEPTH IV study area

International Deep Profiling of Tibet and the Himalaya, phase IV (INDEPTH IV): Large-scale geophysical and geological study of the Tibetan Plateau

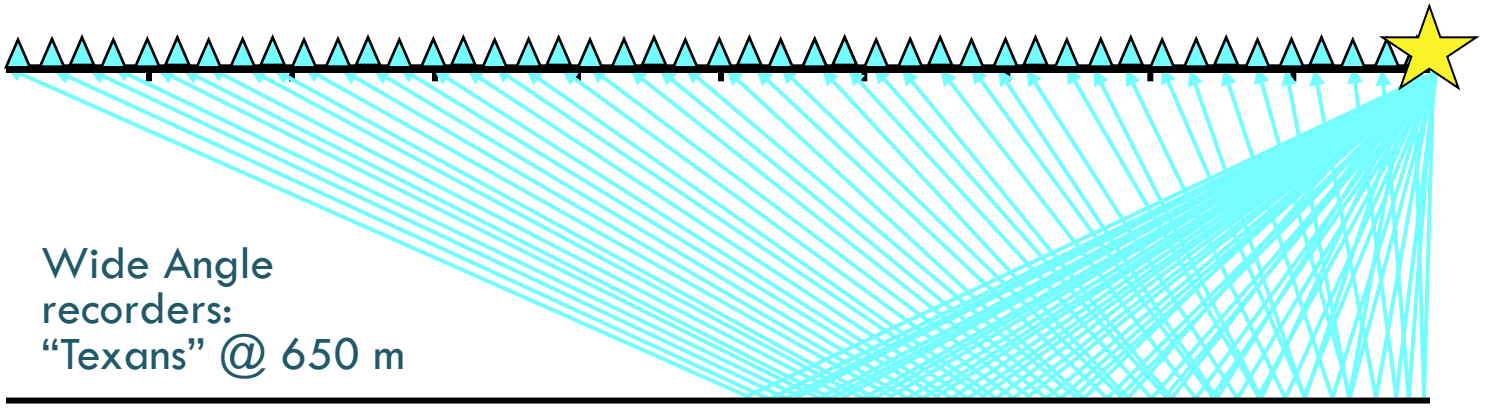


Recording p-waves from explosive sources

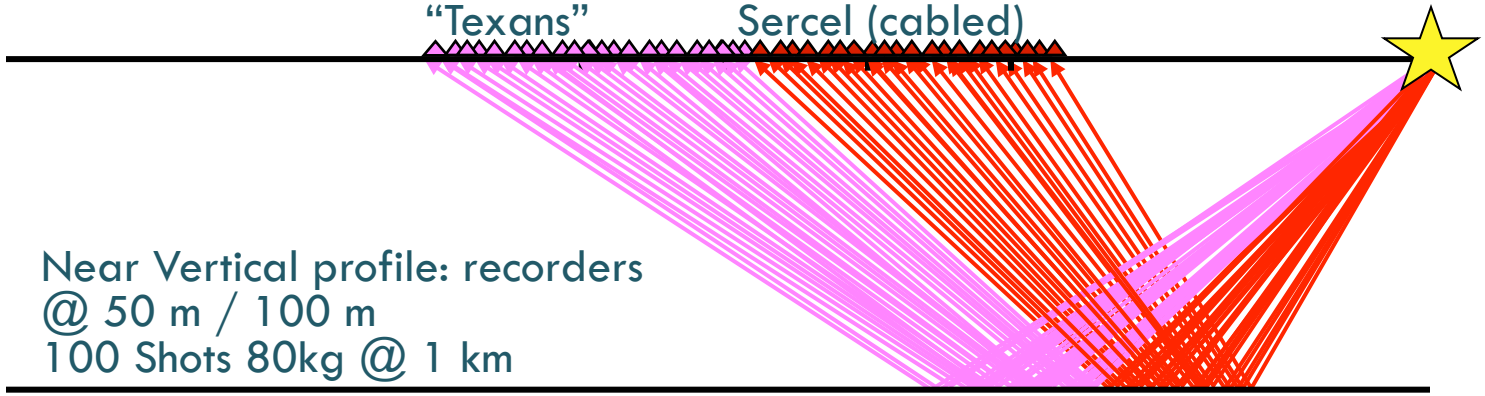




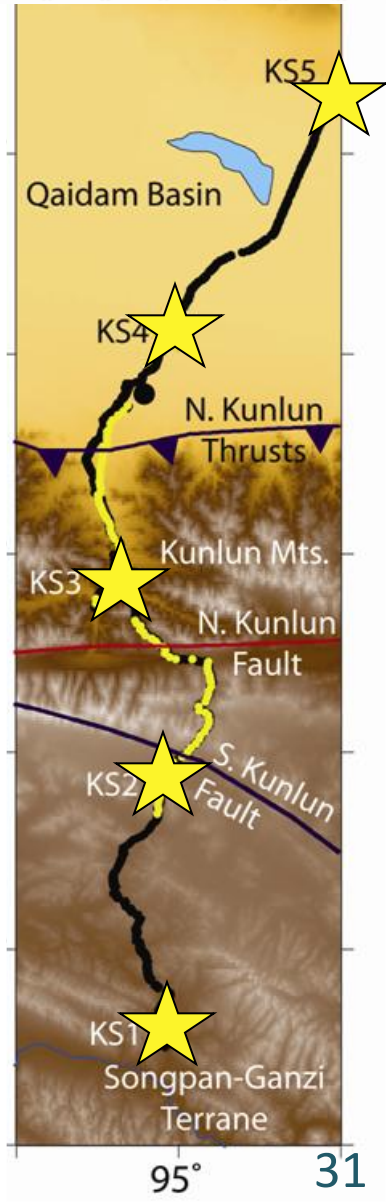
3 component recorders:
Mark 1 Hz @ 6 km



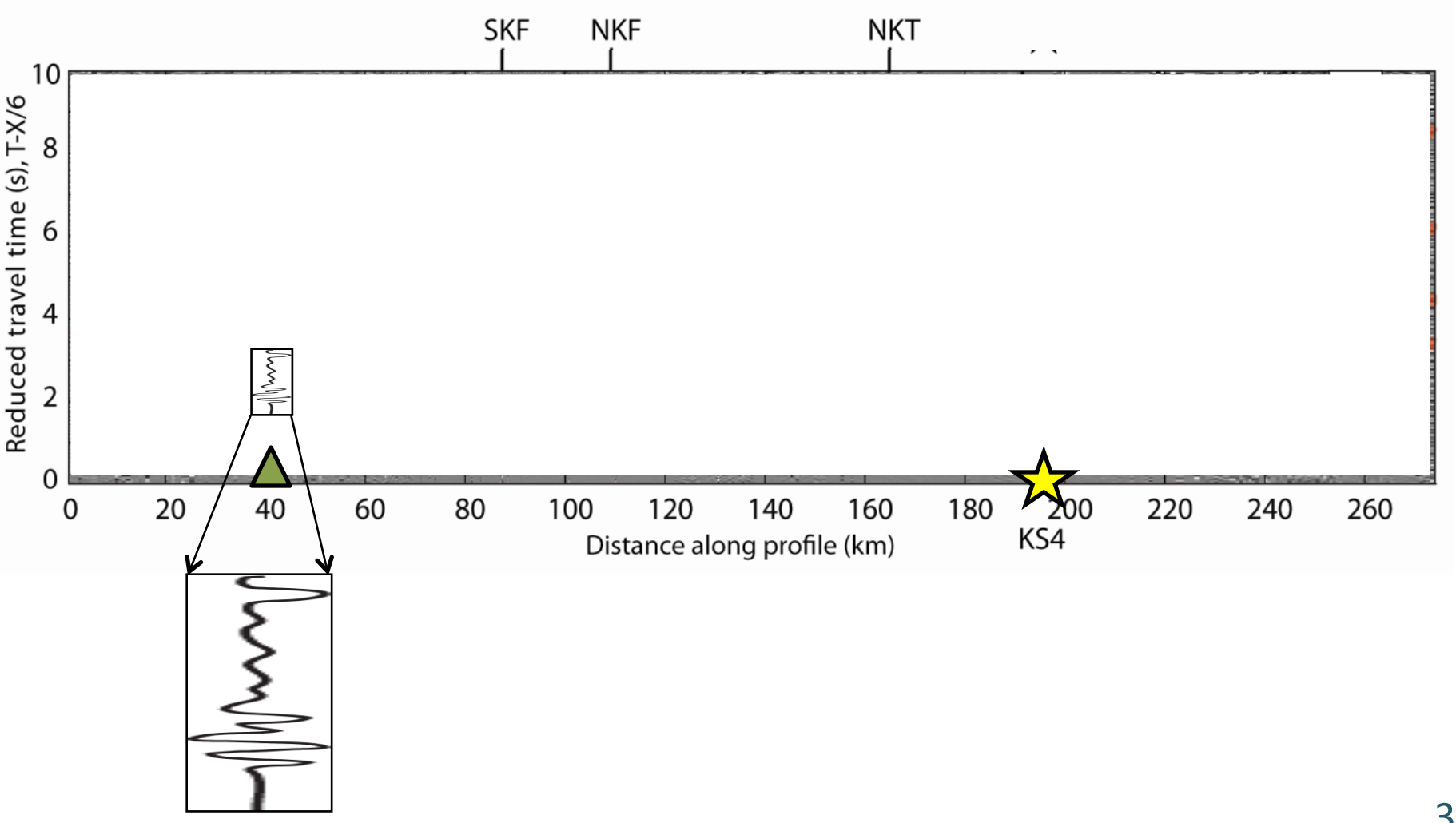
Wide Angle recorders:
"Texans" @ 650 m



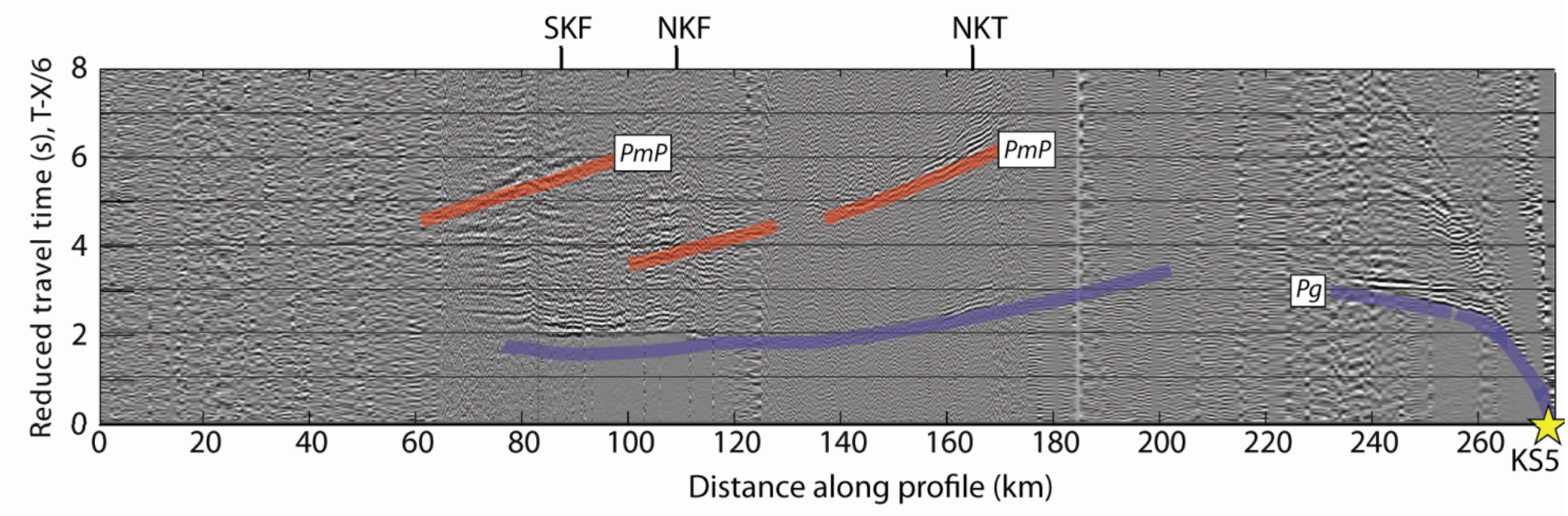
Near Vertical profile: recorders
@ 50 m / 100 m
100 Shots 80kg @ 1 km



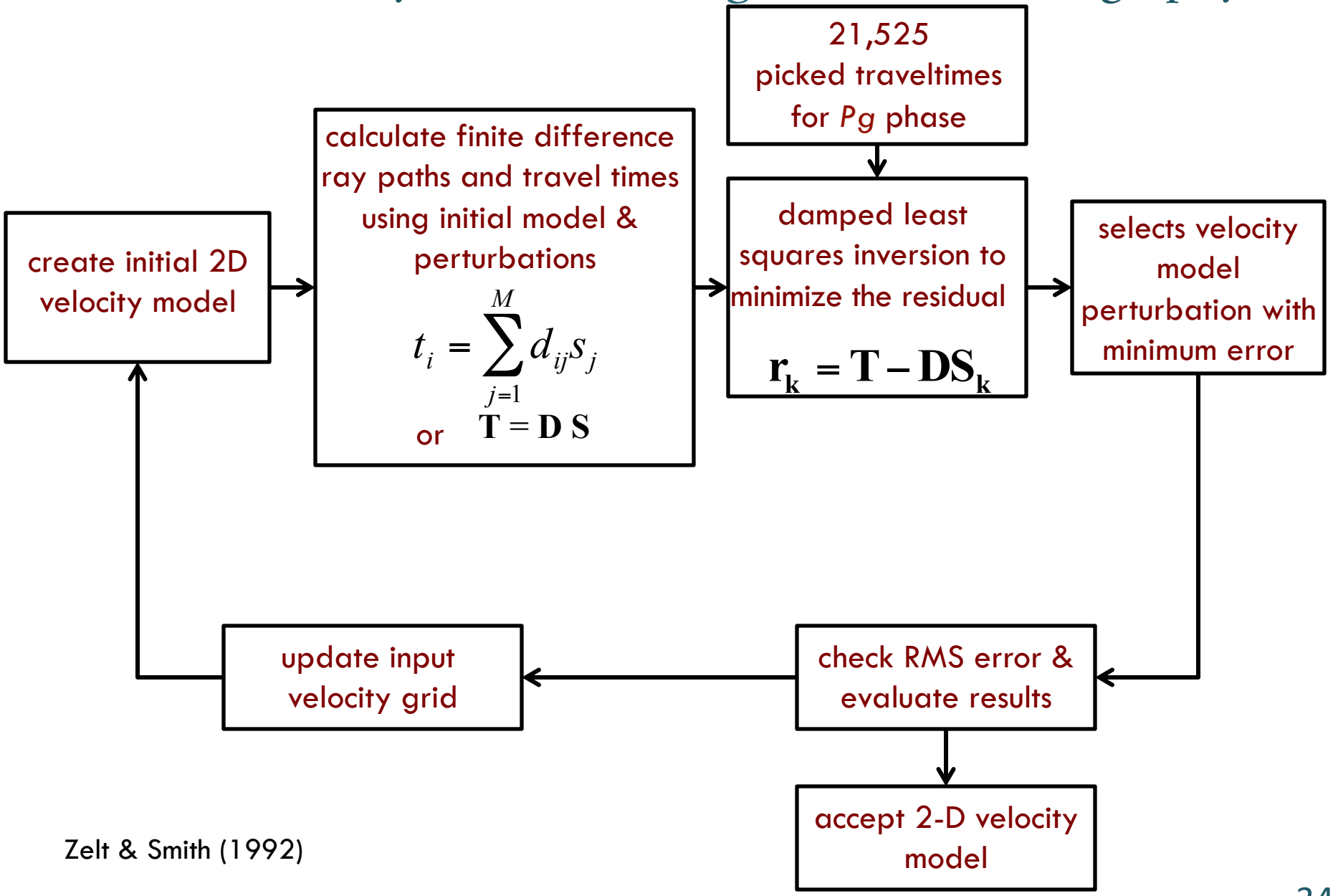
Wide-angle reflections and refractions from KS4



Wide-angle reflections and refractions from KS5

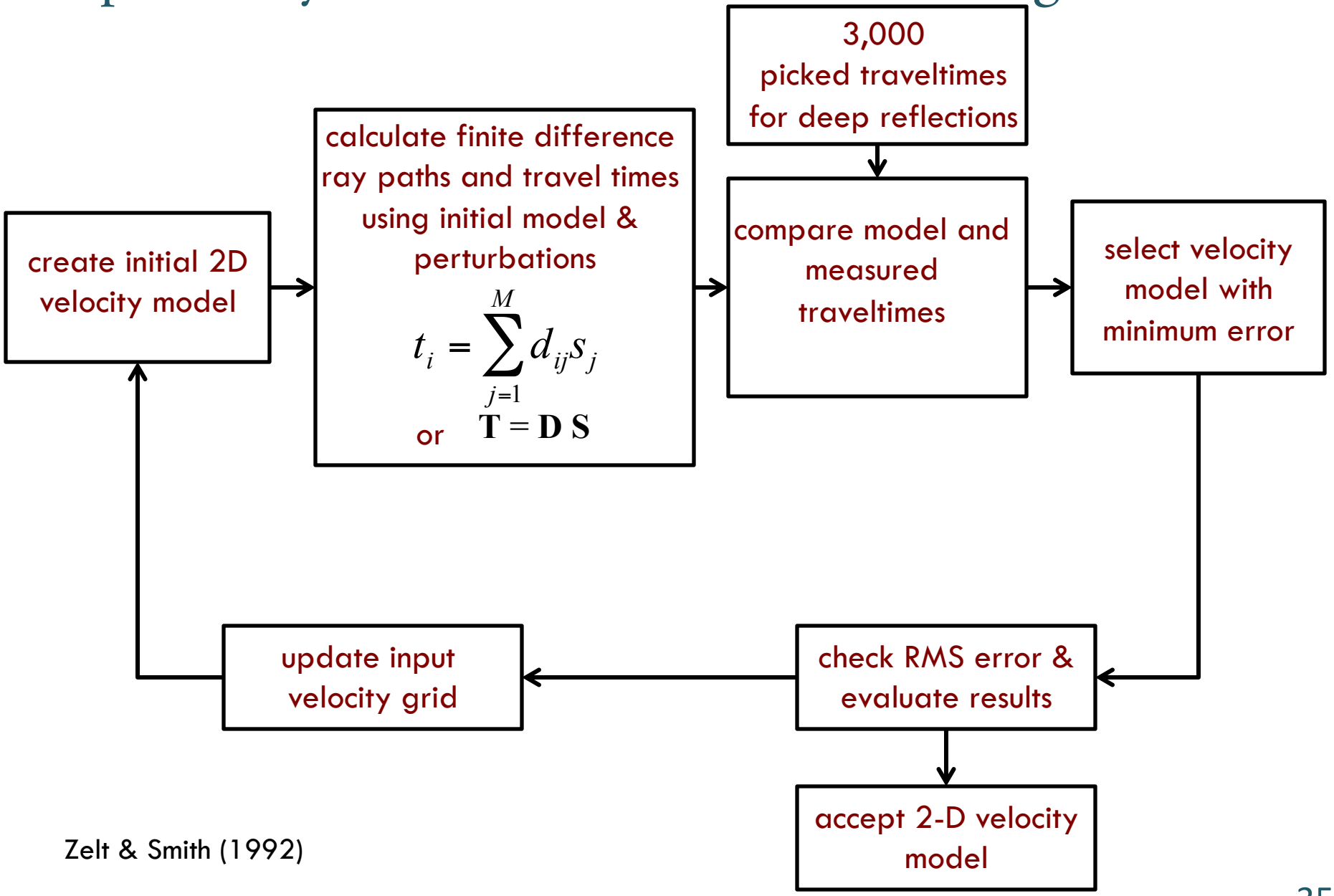


Shallow velocity model from *Pg* refraction tomography



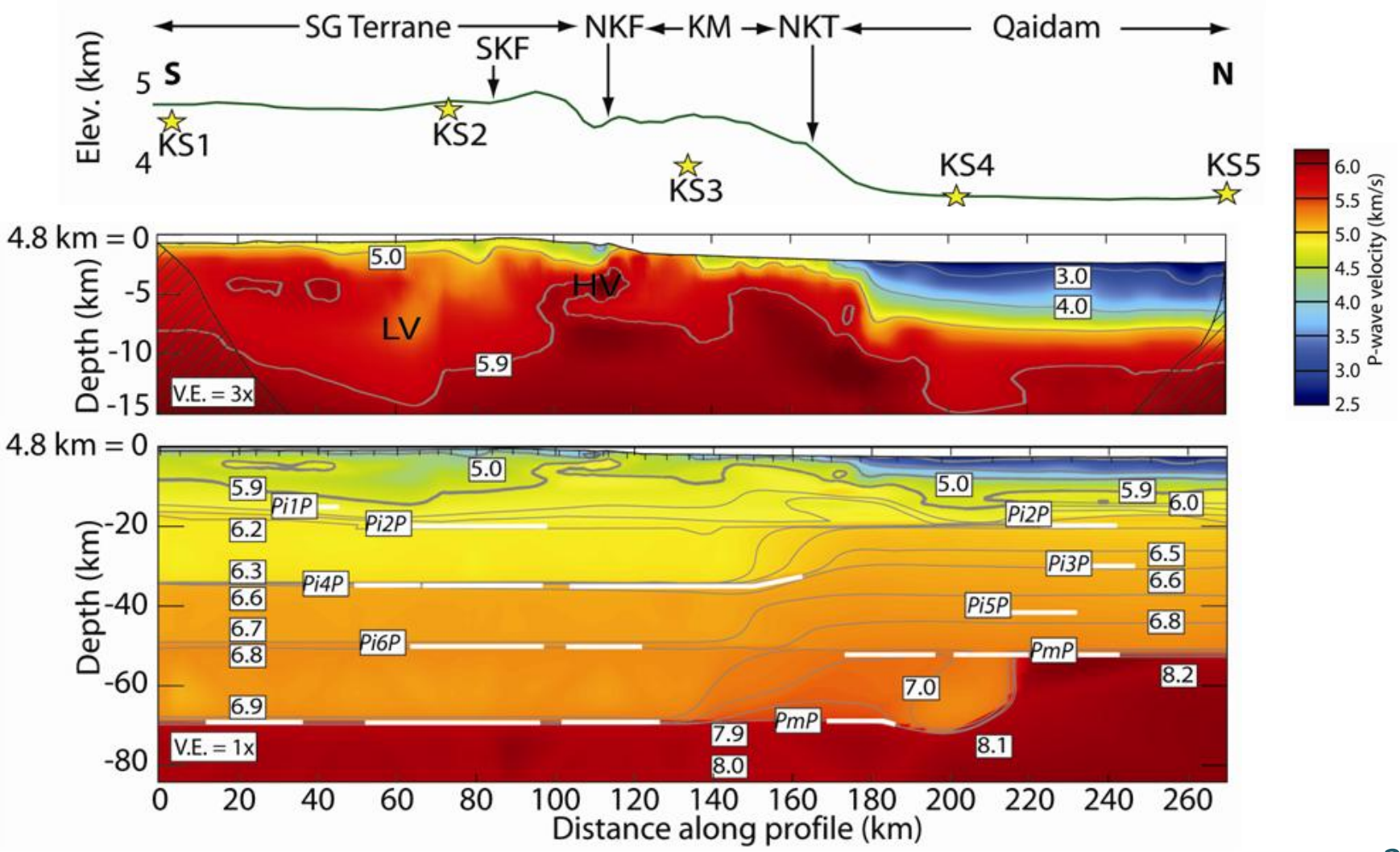
Zelt & Smith (1992)

Deep velocity model from forward modeling reflections



Zelt & Smith (1992)

Example outcome first arrivals tomography & deep reflection forward modeling: crustal velocity models



Research vignette III: Marine reflection & refraction in the Black Sea

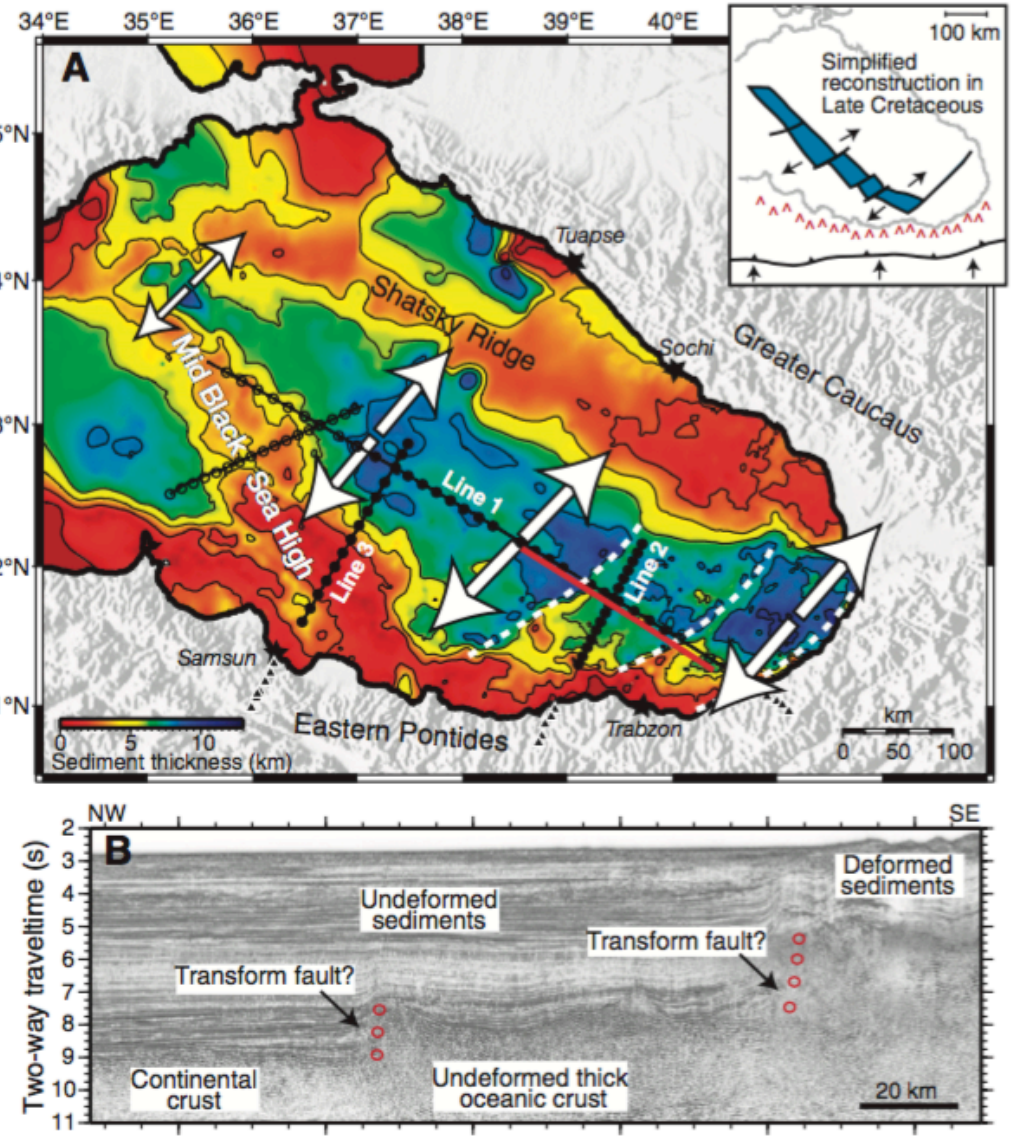
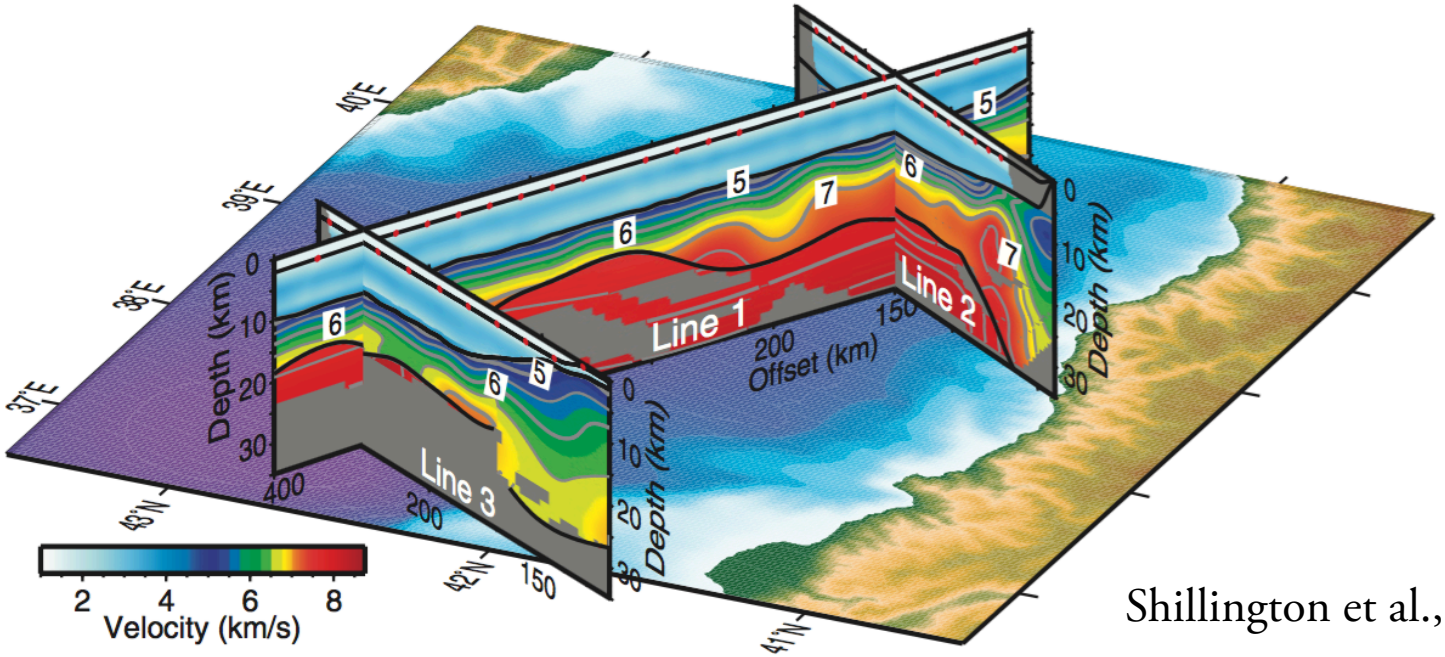


Figure 1. A: Location of 2005 Black Sea wide-angle seismic experiment. Sediment thicknesses estimated from seismic reflection data are shown within eastern Black Sea basin (Shillington et al., 2008), and illuminated elevation from the GEBCO (General Bathymetric Chart of the Oceans) Digital Atlas (published by the British Oceanographic Data Centre on behalf of the International Hydrographic Organization [IHO] and the Intergovernmental Oceanographic Commission [IOC] of UNESCO; IOC, IHO, and BODC, 2003) is shown onshore. Arrows are scaled by the amount of stretching, which was estimated from subsidence analysis (Shillington et al., 2008). Note that extension increases eastward to reach a maximum stretching factor (initial/final crustal thickness) of ~5. Locations of ocean-bottom seismometers, land seismometers, and shot profiles are indicated with black circles, triangles, and lines, respectively. Filled circles indicate parts of each line shown in Figure 2. Red line indicates location of profile in B. Thin dotted white lines indicate locations of interpreted transform faults described in text. Inset shows simplified reconstruction of tectonic structures relevant to this study in the Late Cretaceous (modified after Okay et al., 1994). Blue shaded areas represent either highly thinned continental crust or oceanic crust. Red inverted v symbols represent approximate region of island arc magmatism, and arrows indicate approximate relative plate motions. Subduction zone is indicated by line with triangles (where northern plate was upper plate). B: Seismic reflection profile oriented perpendicular to direction of basin opening in eastern Black Sea. Red dots indicate possible transform faults, which are shown with dotted lines in A.

Shillington et al., 2009

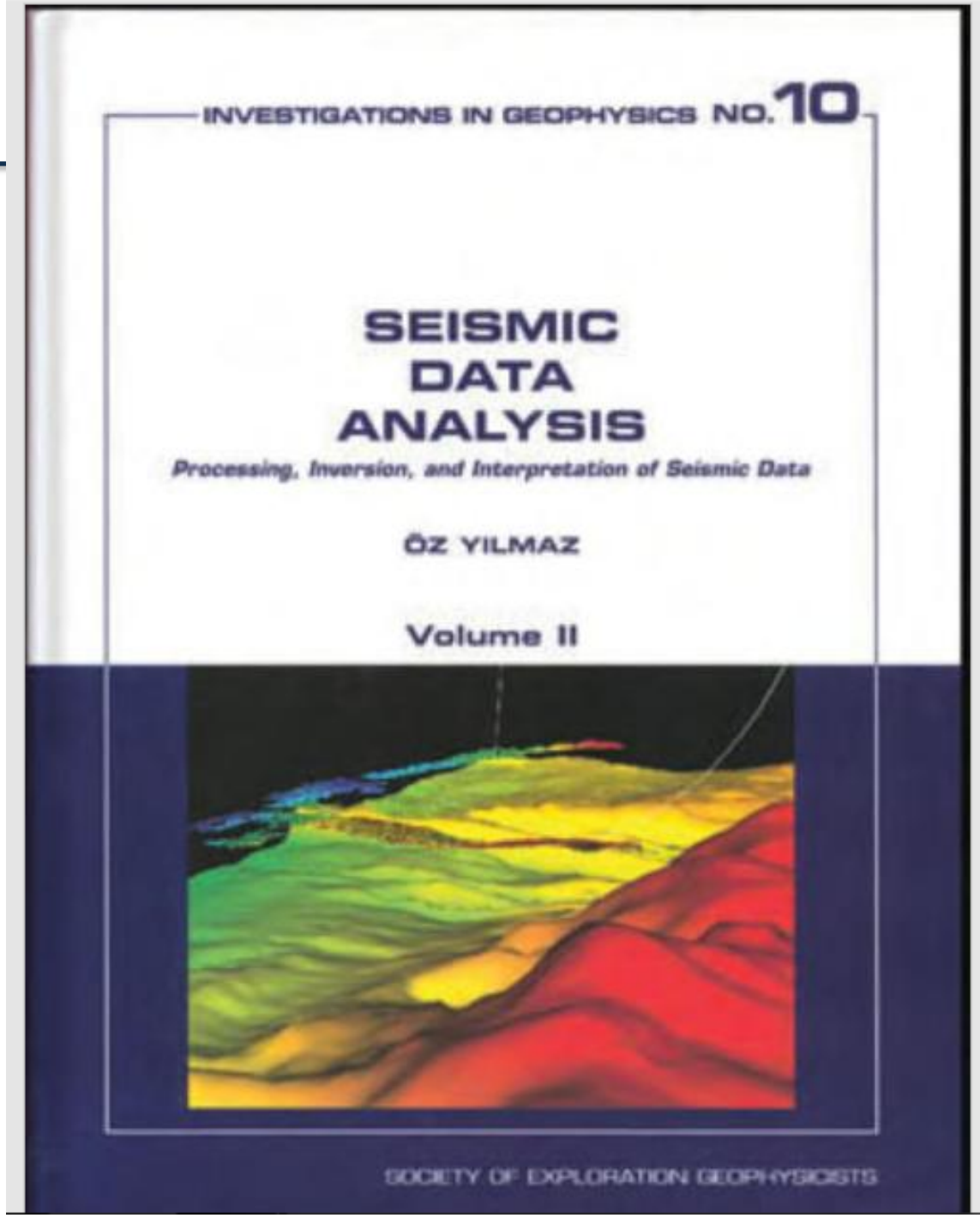
Marine reflection & refraction in the Black Sea



Shillington et al., 2009

Figure 2. Fence diagram showing velocity models from lines 1, 2, and 3 (see Fig. 1A for locations). Color scale represents variations in compressional wave velocity. Velocities >4 km/s are also contoured every 0.5 km/s. Bold lines mark top and base of the crust. Bathymetry is taken from the GEBCO Digital Atlas (IOC, IHO, and BODC, 2003). Note eastward increase in crustal thickness and increase in lower crustal velocity that occurs at model km 230 on line 1.

Processing resource



Also, Sheriff & Geldart, 1995
Exploration Seismology

Finding a dataset

- If you are doing passive data processing, maybe there is an active-source dataset nearby?
- What kind of analysis will you do?
  - Reflection?
  - Refraction?
  - Other signal processing?
- What hypotheses do you want to test?

Finding a dataset

- Eastern North America community experiment
- General info: http://geoprisms.org/initiatives-sites/rie/enam/
- Onshore/ offshore data: http://www.ig.utexas.edu/sdc/DOI/datasetDOI.php?datasetuID=500018
- Marine data: http://www.ig.utexas.edu/sdc/cruise.php?cruiseIn=en546

Finding a dataset – nodes

- Sweetwater, Texas data
- http://ds.iris.edu/mda/XB?timewindow=2014-2014
- http://ds.iris.edu/gmap/XB?timewindow=2014-2014

- Oklahoma IRIS wavefields experiment (coming soon!)

NE Tibet INDEPTH IV data

- http://ds.iris.edu/SeismiQuery/bin/assembled.pl
- https://pangea.stanford.edu/researchgroups/crustal/sites/default/files/Karplusetal.IN4WA.pub_.2011.pdf

Finding a dataset

- Search IRIS for assembled SEGY datasets: http://ds.iris.edu/SeismiQuery/assembled.phtml

- Search UTIG or LDEO Academic seismic portals:

http://www.ig.utexas.edu/sdc/

http://www.marine-geo.org/portals/seismic/

Seismic processing software: Landmark SeisSpace/ ProMAX

https://www.landmarksoftware.com/Pages/SeisSpaceProMAX.aspx

- ProMAX 2D
- ProMAX 3D

ProMAX 4D
ProMAX VSP
ProMAX Field

Other seismic processing

- Paradigm Focus

- Dolphin Geophysical OpenCPS

Refraction velocity modeling

- Colin Zelt: RAYINVR, ZP, …
  http://terra.rice.edu/department/faculty/zelt/rayinvr.html
- John Hole: FAST 2D, FAST 3D, …
  http://www.geophys.geos.vt.edu/hole/software.html
- Cerveny SEIS81, ...
  talk to Europeans (or me...)
- MATLAB options exist, but I don't know how robust they are
- SAC and earthquake tomography tools
- Full waveform inversion (e.g., Joanna Morgan, Mike Warner in UK, John Hole in U.S., Stanford Exploration Project (?), others...)

Reflection seismic interpretation

- IHS Kingdom

http://www.ihs.com/products/oil-gas-information/analysis-software/kingdom-seismic-interpretation/index.aspx

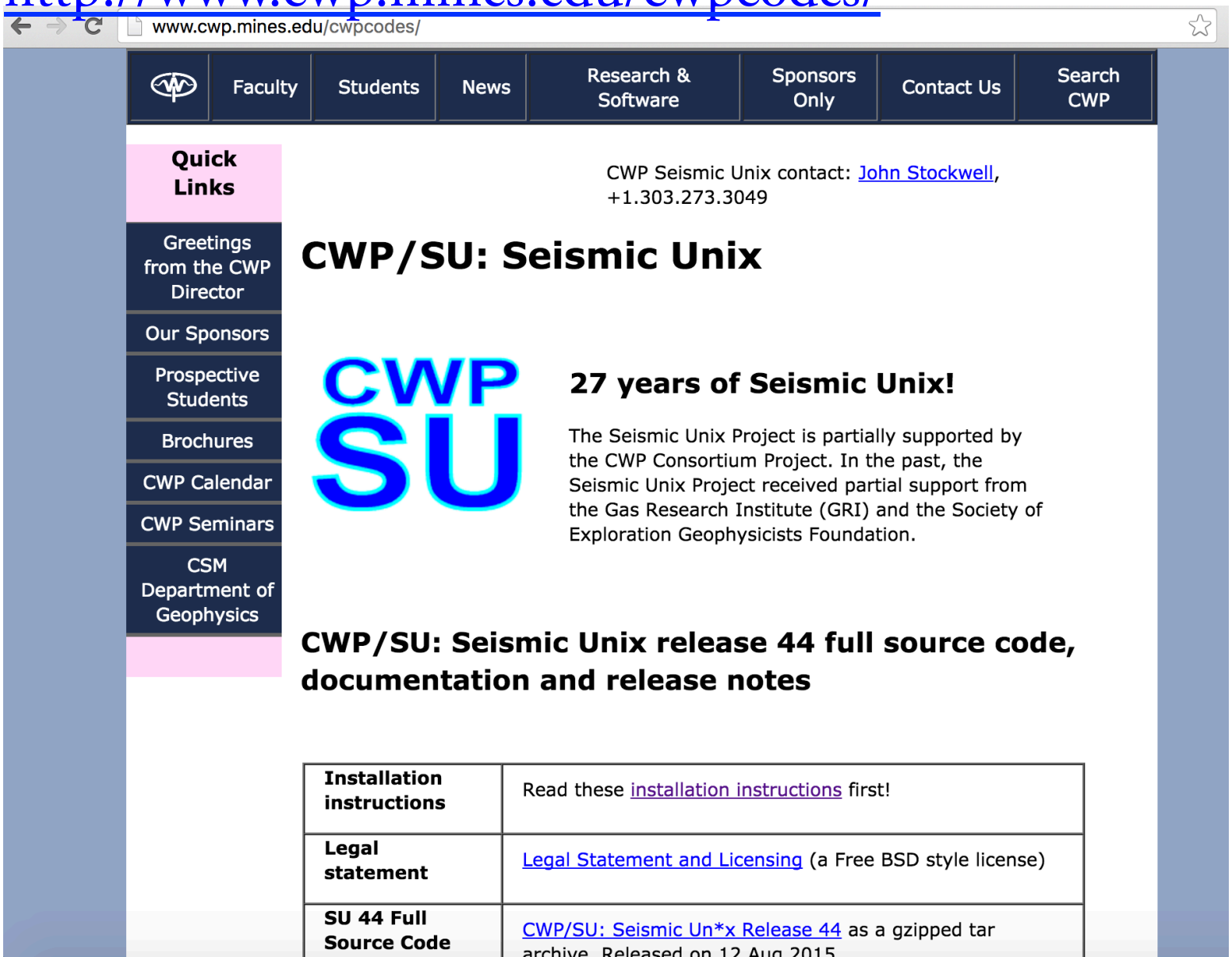
- Opendtect – Open Source seismic interpretation

http://www.opendtect.org/

- SeisWorks – Landmark/Haliburton
- Petrel – Schlumberger
- Matlab options exist, but I don't know how robust they are

Processing the data: Seismic Unix – home page

http://www.cwp.mines.edu/cwpcodes/

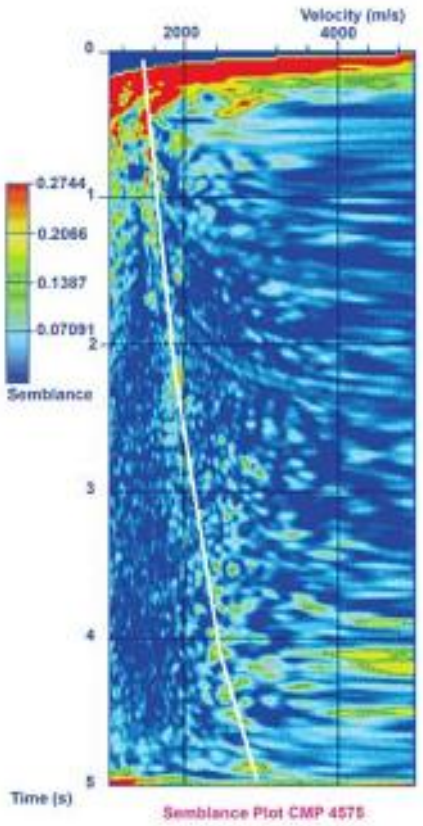


Online tutorial resource: http://library.seg.org/doi/book/10.1190/1.9781560801948

Seismic Data Processing with Seismic Un*x

A 2D Seismic Data Processing Primer

David Forel, Thomas Benz,
and Wayne D. Pennington



Course Notes Series No. 12
Lawrence M. Gochioco, Series Editor

Society of Exploration Geophysicists

Tips for installing Seismic Unix

- Set environment variables in your bash shell.

- For example:

```
export CWPROOT=/usr/local/CWP
export PATH=$PATH:$CWPROOT/bin
```

Seismic Unix help

- suhelp – list all available SU programs
- suname <program> – list SU programs with short description
- sudoc <program> – program documentation
- sufind <keyword> – search sudoc for keyword
- sukeyword –o – list header variables

Pipe (|), redirect out (>), redirect in (<)

- $ suplane | suxwigb (pipe)
- $ suplane > test.su (redirect out)
- $ suxwigb < test.su (redirect in)
- $ suplane | suxwigb & (ampersand)

(& frees up the terminal and runs the process in the background)

Basic examples

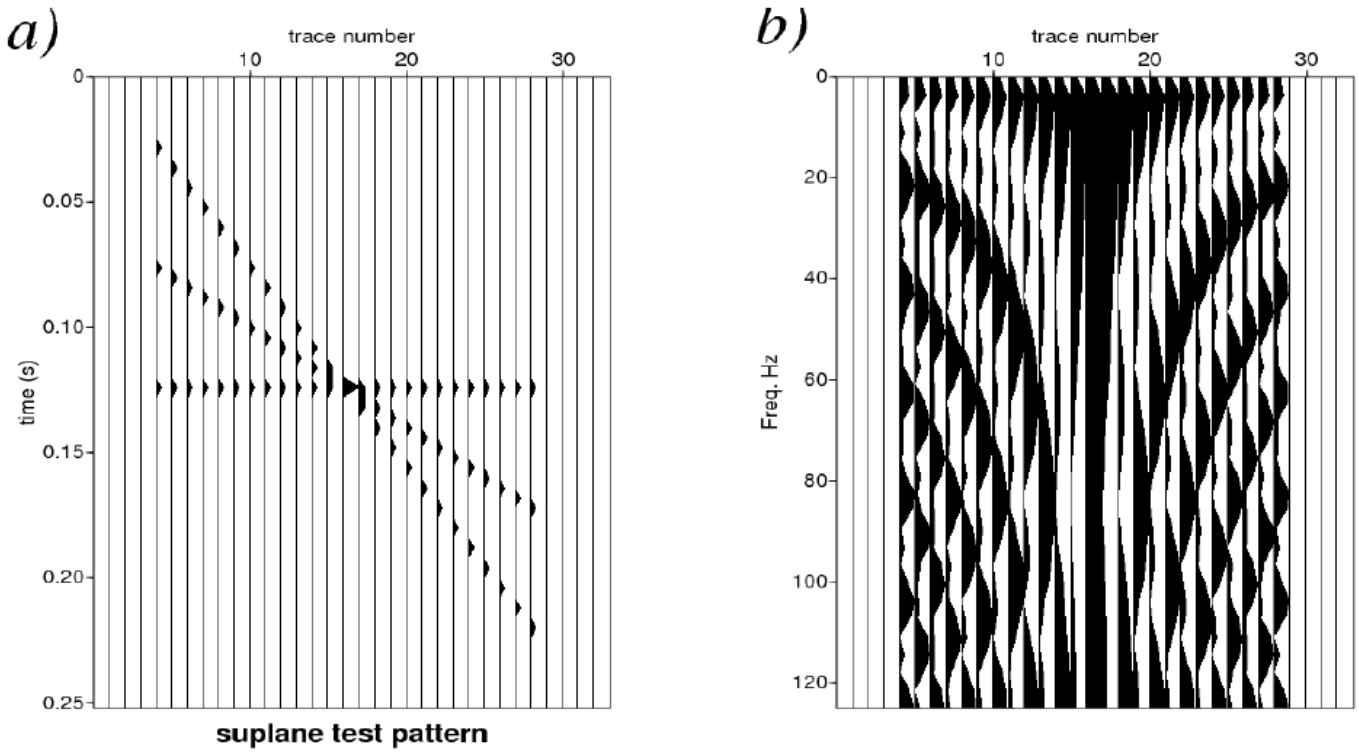
> suplane | suxwigb (Create 32 traces with 3 planes)

> suplane | suspecfx | suxwigb (Fourier spectrum of traces)

> suplane > test.su

> suspecfx < test.su > test2.su

> suxwigb < test2.su label1='freq (Hz)' label2='trace number'



Seismic Unix – data/header manipulation

> segyread - read SEG-Y standard files
> segywrite - write SEG-Y standard files
> sukeyword –o - prints a complete list of header values
> surange - provides the range of header values for a dataset

Copy data file B49.segy from the shared USArray folder.

First we need to read that file into SU. Create a text file called read_data.csh, and type the following into that file:

segyread tape=B49.segy conv=1 endian=0 | segyclean > B49.su

Now try:

surange < B49.su
sugethw < B49.su key=sx | more
sukeyword sx

>sugethw - gets the header values from each trace
>sushw - sets a new header value for each trace
>suwind - window trace data by keyword

http://www.seismicunix.com/w/Seismic_Unix_data_format

What is a SEGY file?

To get a better idea of this, go to the Wikipedia page for SEG-Y: https://en.wikipedia.org/wiki/SEG_Y . Basically, a SEG-Y file has a 3200 byte textual EBCDIC header (EBCDIC is an 8-bit character encoding system), a 400 byte binary reel header, and the seismic traces, which could be in one of ~5 formats:

1: IBM floating point, 4 byte (32 bits)
2: two's complement integer, 4 byte (32 bits)
3: two's complement integer, 2 byte (16 bits)
5: IEEE floating point, 4 byte (32 bits)
8: two's complement integer, 1 byte (8 bits)

[Note: one byte = 8 bits]

Seismic Unix – trace display

suximage - X windows image plot

suwigb - X windows bit-mapped wiggle plot

supsimage - postscript image plot

supswigb - postscript bit-mapped wiggle plot

supswigp - postscript polygon-filled wiggle plot

spsplot - plot postscript velocity models

ximage - uniformly sampled X image plot

Seismic Unix – trace display

Write another script file to read in the *.su file and create a postscript display of it.

```
sufilter f=3,6,16,32 < B49.su | sureduce rv=8 | supswigb
nbpi=300 f1=0.0 wt=0 va=1 x1beg=0 x1end=10
x2beg=-45000 x2end=99000 verbose=1 key=offset
d1num=2.0 n1tic=5 n2tic=5 perc=70 bias=0 labelsize=14
linewidth=10 wbox=4.664 hbox=2.5 label1="Time (sec)"
label2="Offset (m)" > B49.ps
```

Try changing the filter parameters and see what happens.

suxwigb/suximage

X Functionality:

Button 1	Zoom with rubberband box
Button 2	Show mouse (x1,x2) coordinates while pressed
q or Q key	Quit
s key	Save current mouse (x1,x2) location to file
p or P key	Plot current window with pswigb (only from disk files)
a or page up keys	enhance clipping by 10%
c or page down keys	reduce clipping by 10%
up,down,left,right keys	move zoom window by half width/height
i or +(keypad)	zoom in by factor 2
o or -(keypad)	zoom out by factor 2
l	lock the zoom while moving the coursor
u	unlock the zoom
1,2,...9	Zoom/Move factor of the window size

Seismic Unix – trace display

Try this script:

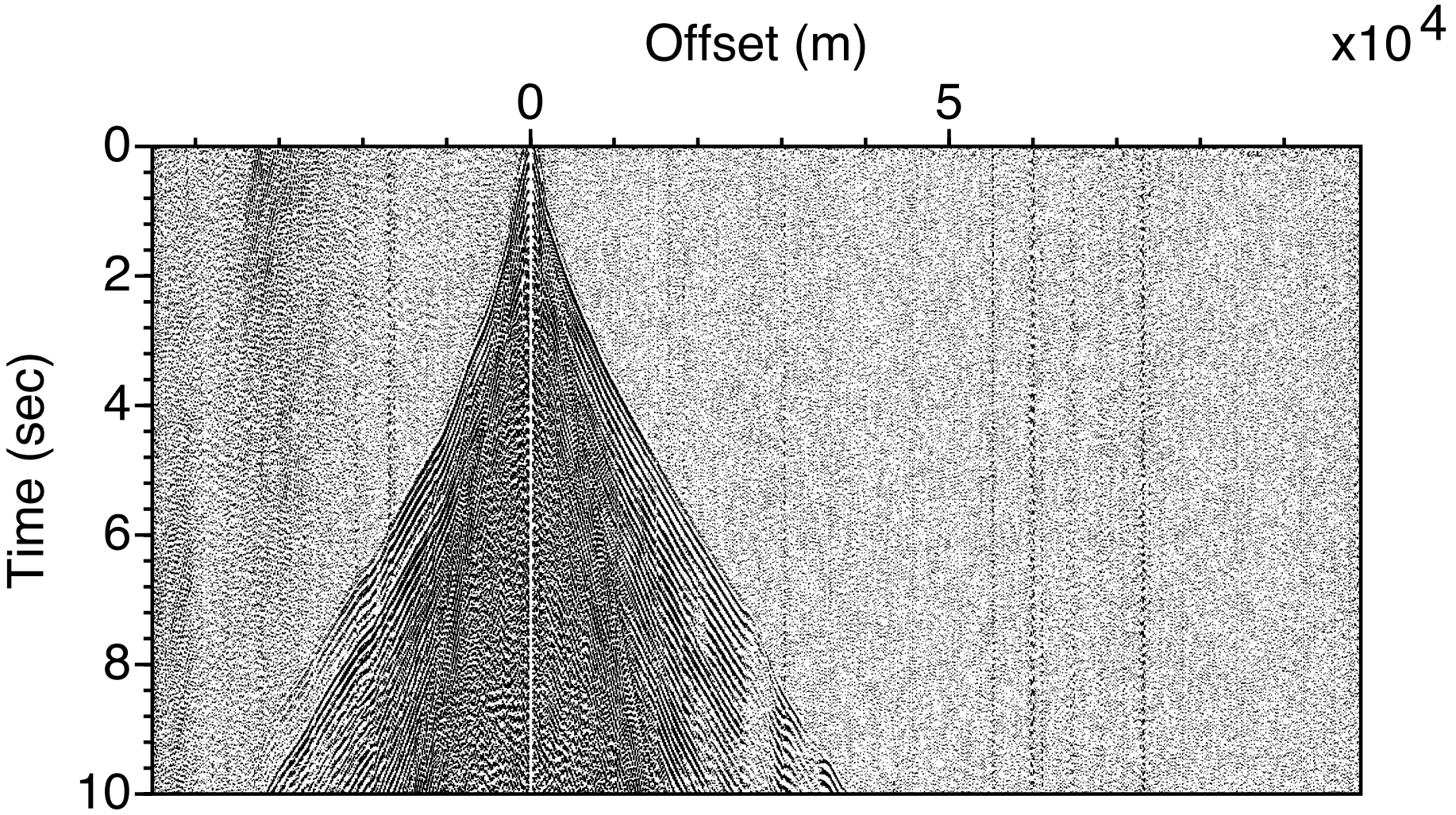
```
sufilter < B49.su f=0,5,30,40 | sureduce rv=6 | supswigb
key=offset xcur=1 clip= perc=75 wt=0 va=1 nbpi=600
wbox=2.5 hbox=6.25 x1beg=10.0 x1end=0.0 d1num=5
n1tic=5 n2tic=5 x2beg=-45000 x2end=99000
f2num=-80000 d2num=20000 n2tic=0 style=normal
axescolor=black verbose=1 label1="Time (sec)"
label2="Offset (m)" > B49_dw.ps
```

Seismic Unix – trace display

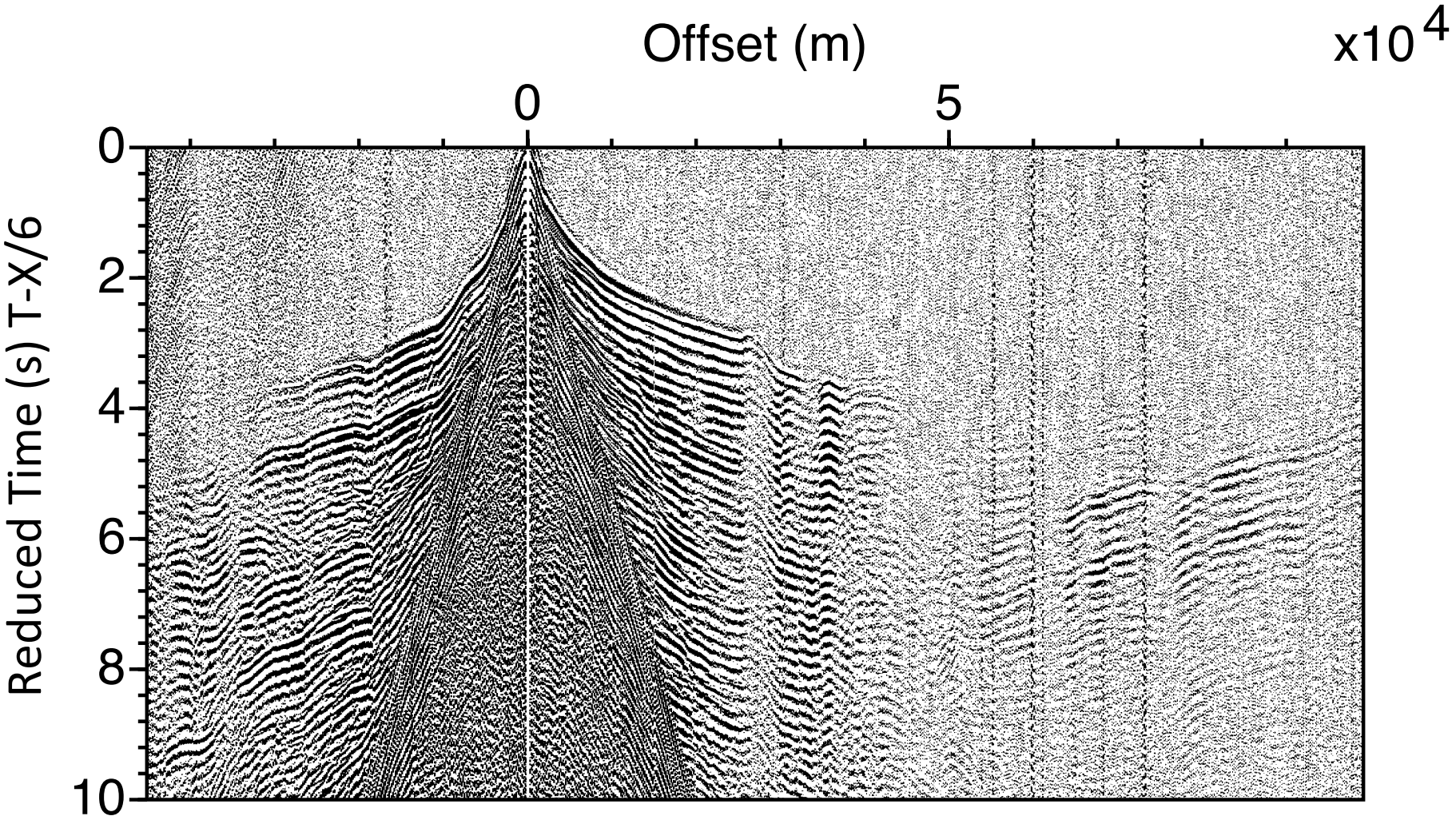
If you want a grayscale image instead of a wiggle image, use supsimage like this:

```
sufilter < B49.su f=3,6,14,28 amp=0,0,1,1 | sureduce rv=6 |
suwind tmin=0 tmax=10 | supsimage key=offset wbox=4.664
n1tic=5 n2tic=100 titlesize=10 labelsize=10  hbox=2.5
title="B49 BP 3-6-14-28" perc=99 > B49_im.ps
```

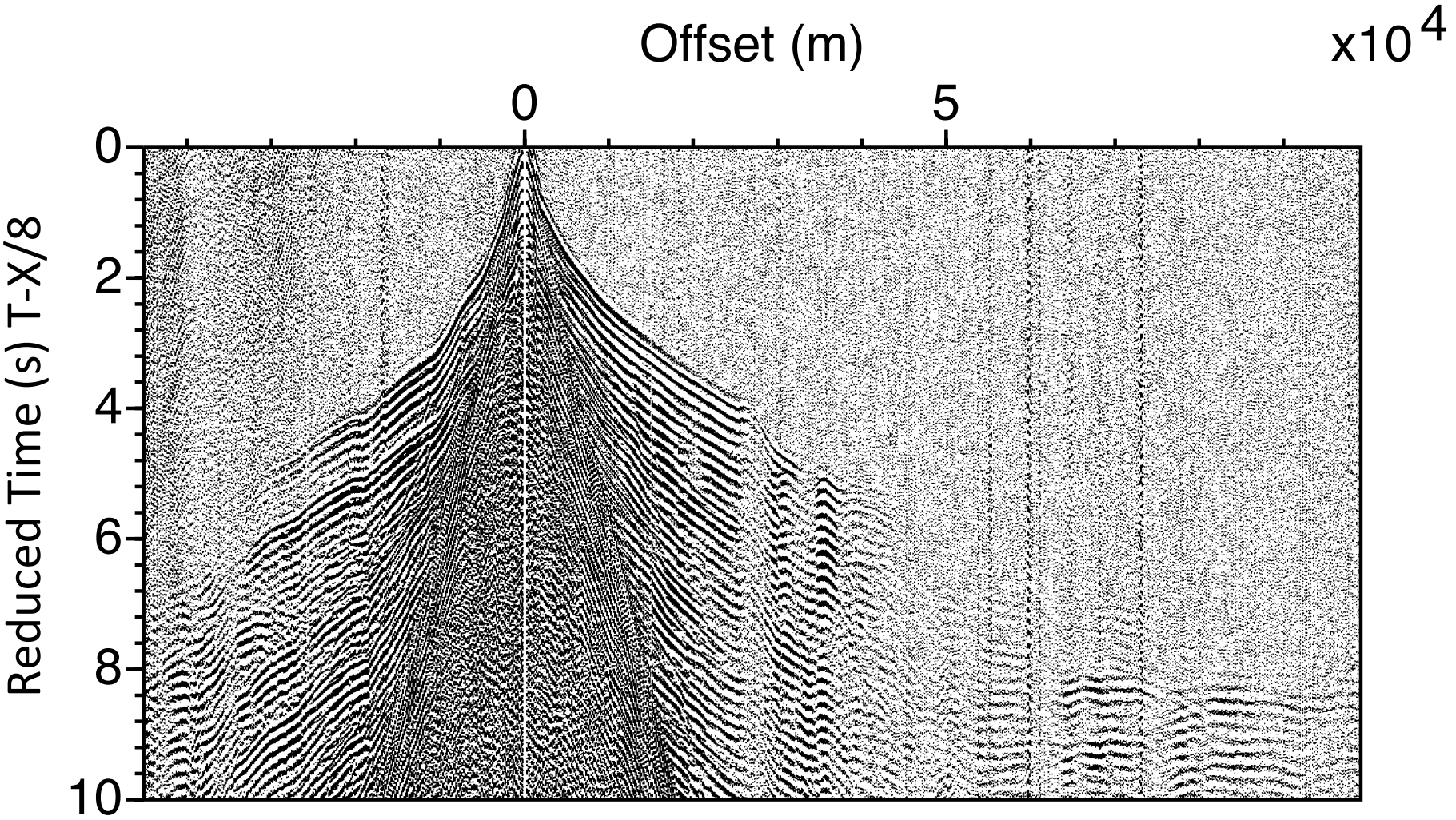
Data examples (B49)



Data examples (B49), reducing velocity 6 km/s



Data examples (B49), reducing velocity 8 km/s



Additional processing for single channel data

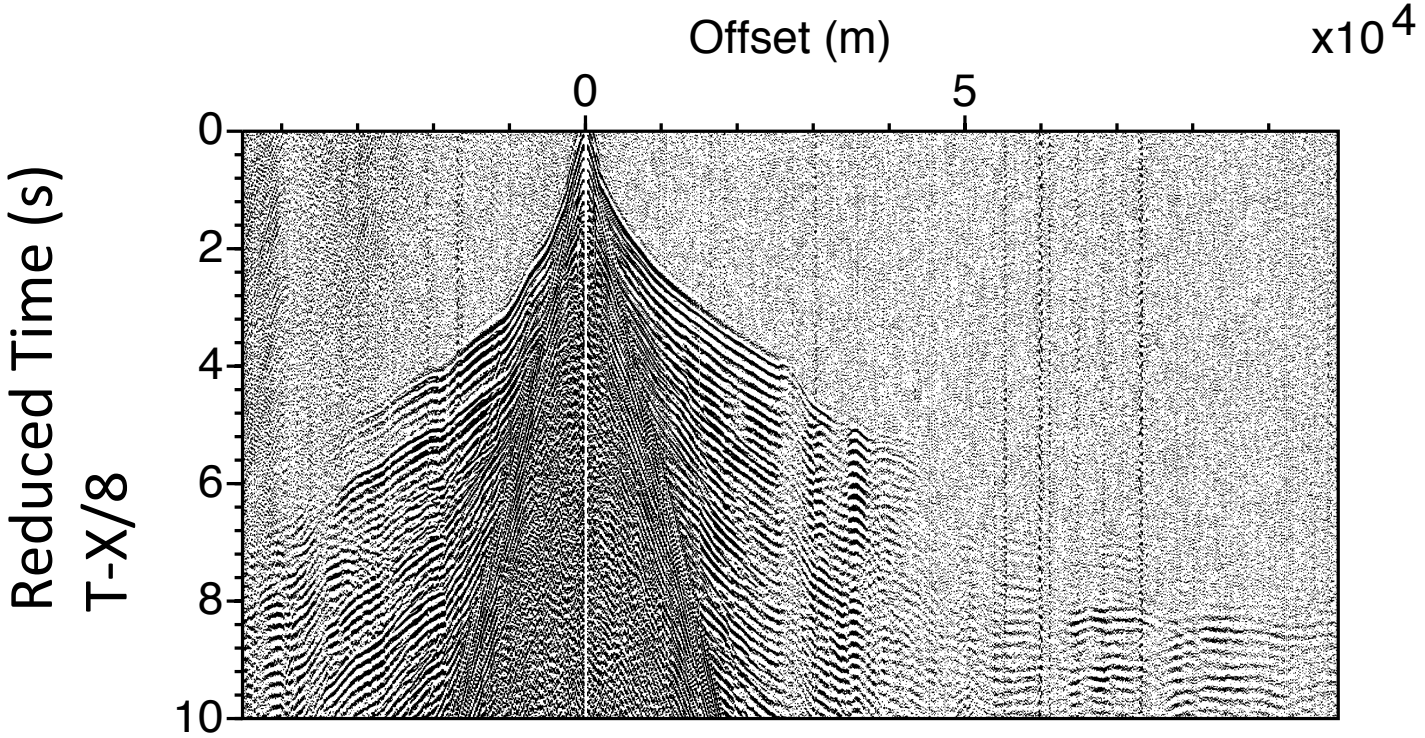
- sufilter → bandpass filter – 1-d operation
- sumix → trace mixing
- sushw → set header word
- sustack → stack on header word
- suop → arithmetic operations
- suop2 → arithmetic operations between 2 datasets
- sugain → trace gain (AGC, amplitude recovery)
- sukill → kill traces

Picking first arriving refractions

> sufbpickw < *.su window=.01 | suximage perc=99

Use sumax to get the values

> sufbpickw < *.su window=.01 | sumax mode=max verbose=1



SU velocity models

- makevel - make a velocity function
- triseis - generate Gaussian beam synthetic seismograms
- sufdmod2 (sufdmod1) – finite difference modelling
- suea2df - (an) **e**lastic **a**nisotropic **2D** **f**inite difference forward modeling, 4th order in space

Setting up geometry in su

sushw - Set one or more header word using trace number, mod and integer divide to compute the header word values or input the header word values from a file

key=cdp,... header key word(s) to set

a=0,... value(s) on first trace

b=0,... increment(s) within group

c=0,... group increment(s)

d=0,... trace number shift(s)

j=ULONG_MAX,ULONG_MAX,... number of elements in group

The value of each header word key is computed using the formula:

- i = itr + d
- val(key) = a + b * (i % j) + c * (int(i / j))
- where itr is the trace number (first trace has itr=0, NOT 1)

Setting up geometry in su

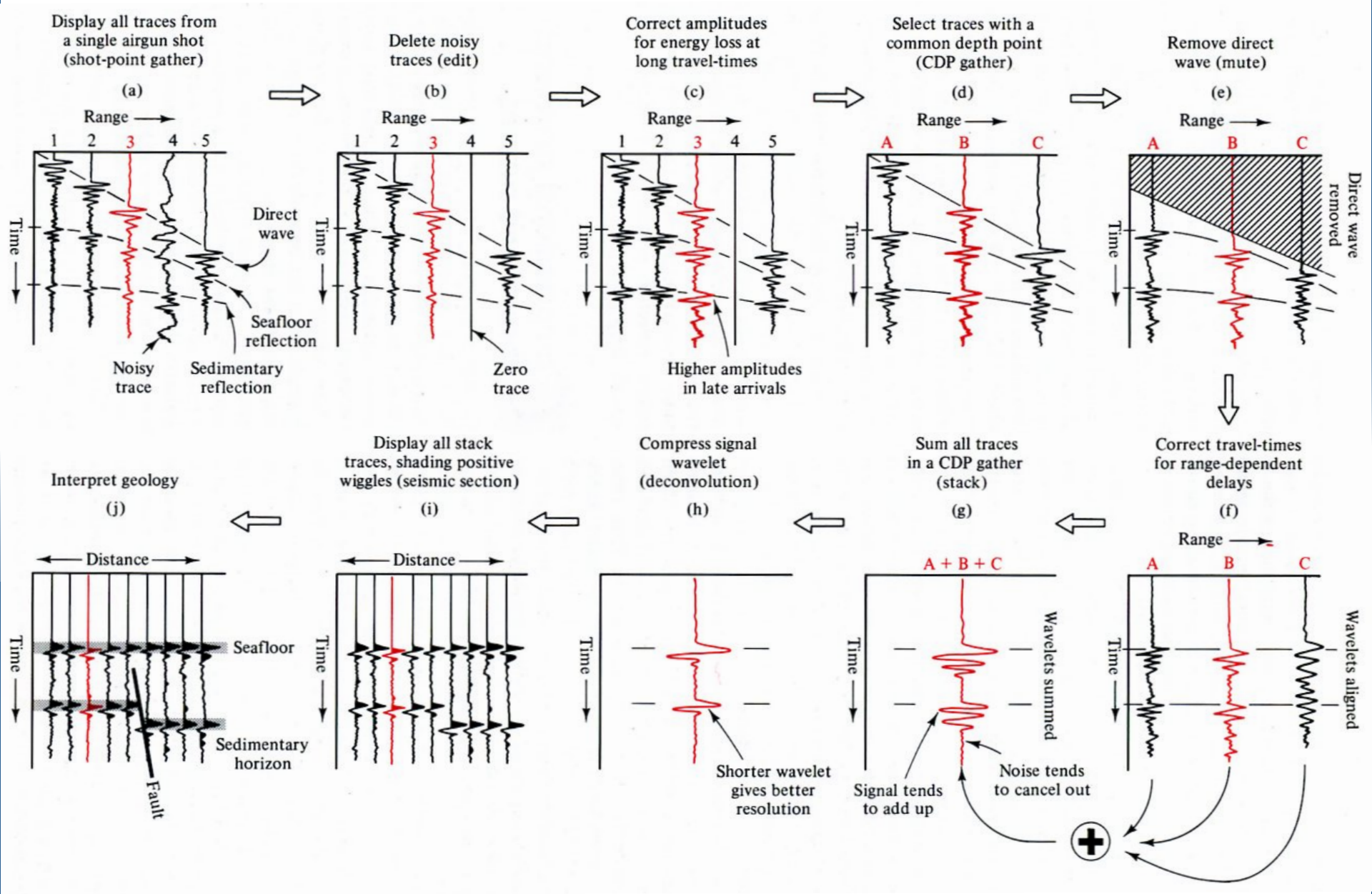
suchw- Change Header Word using one or two header word fields

key1=cdp,...	output key(s)
key2=cdp,...	input key(s)
key3=cdp,...	input key(s)
a=0,...	overall shift(s)
b=1,...	scale(s) on first input key(s)
c=0,...	scale on second input key(s)
d=1,...	overall scale(s)
e=1,...	exponent on first input key(s)
f=1,...	exponent on second input key(s)

The value of header word key1 is computed from the values of key2 and key3 by:

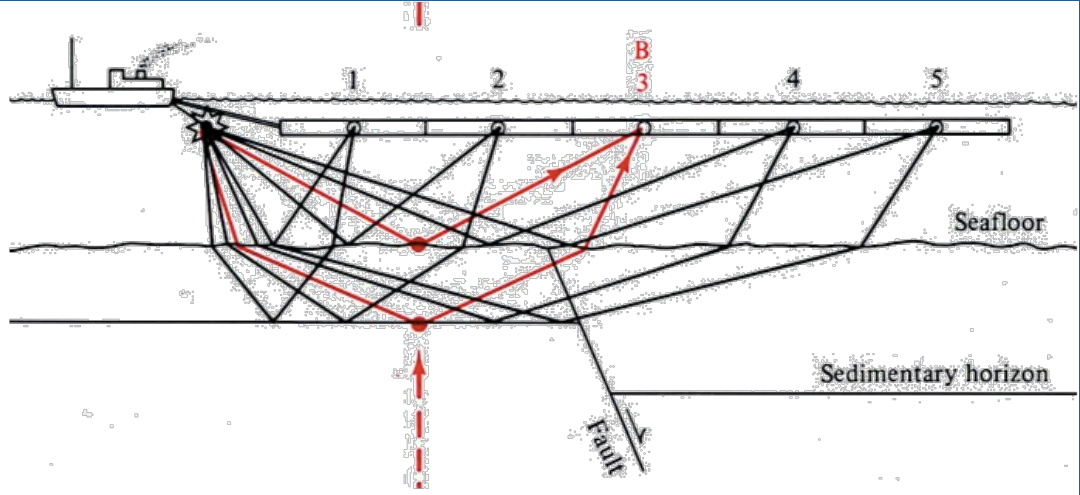
val(key1) = (a + b * val(key2)^e + c * val(key3)^f) / d

Simplified multichannel reflection seismic processing



(Klemperer & Peddy, 1992; Understanding the Earth)

Simplified processing sequence:
pre-processing,
editing,
automatic gain control



Display all traces from a single airgun shot (shot-point gather)

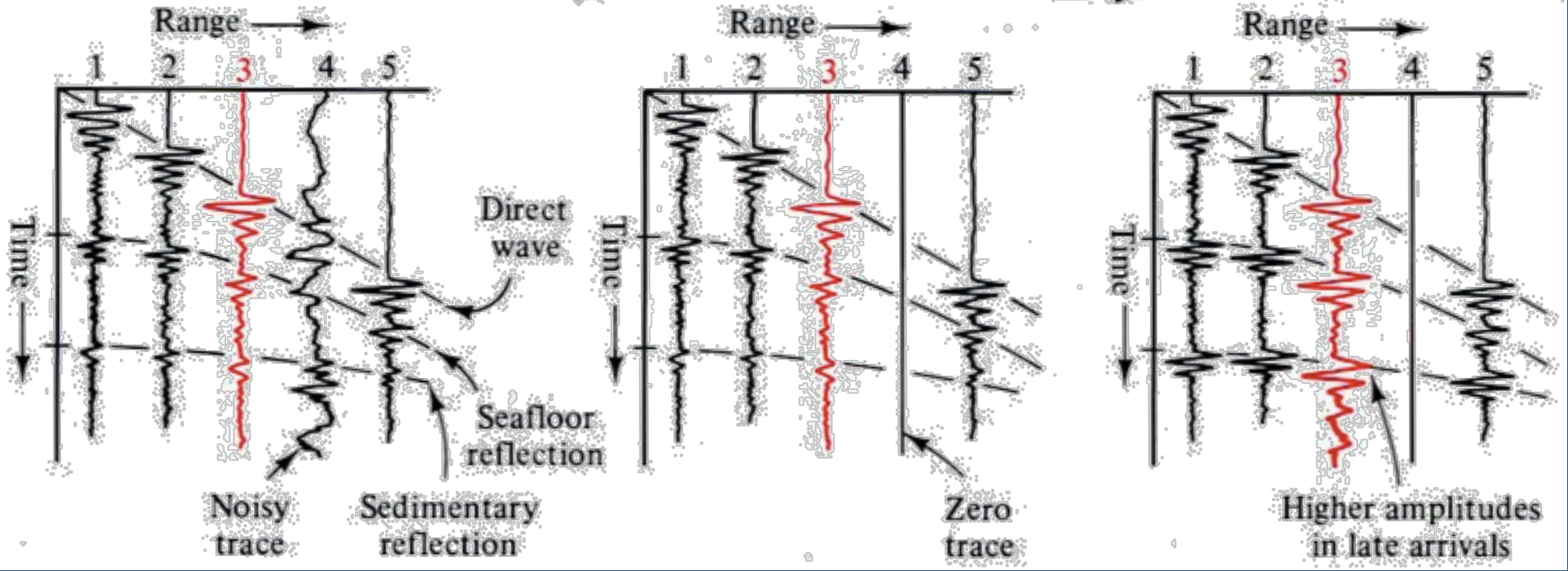
(a)

Delete noisy traces (edit)

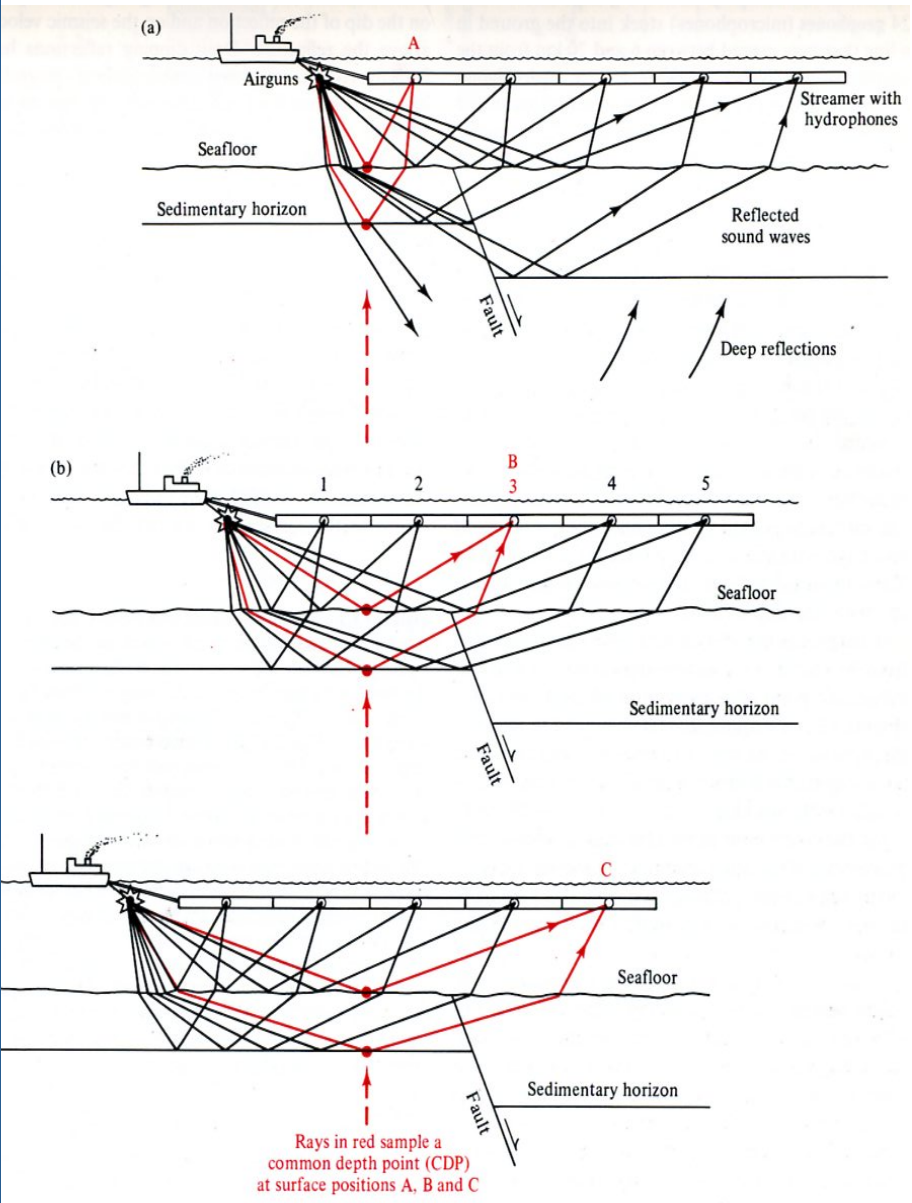
(b)

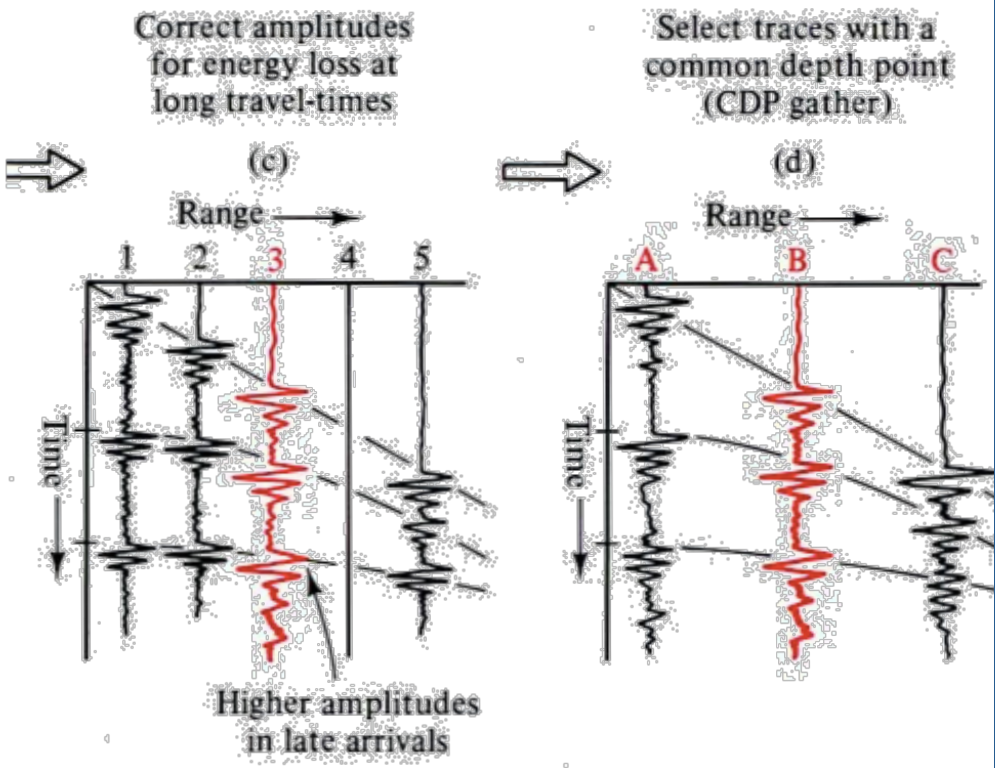
Correct amplitudes for energy loss at long travel-times

(c)



Simplified processing sequence: ***sort into CMPs***

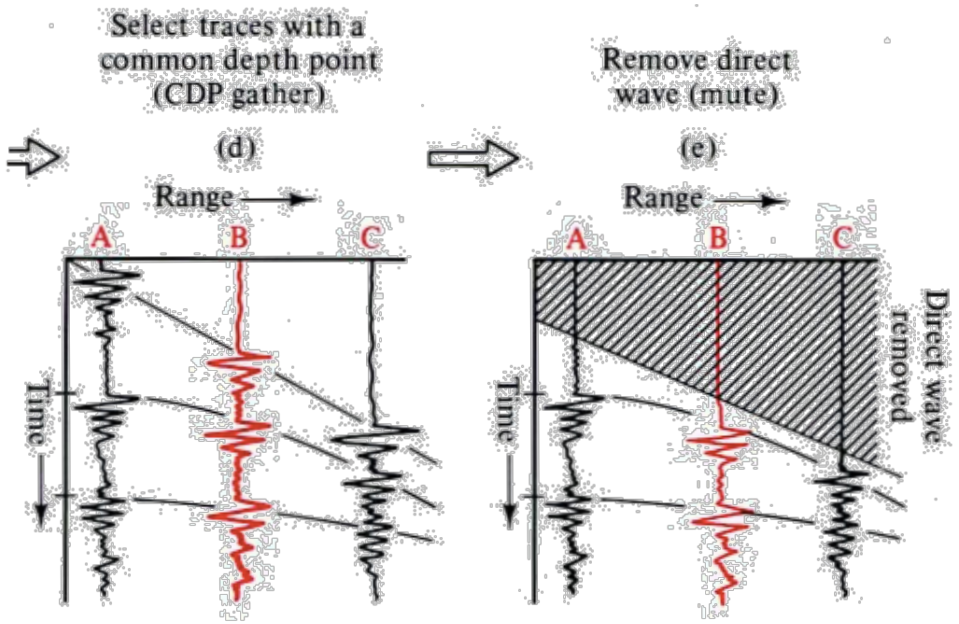


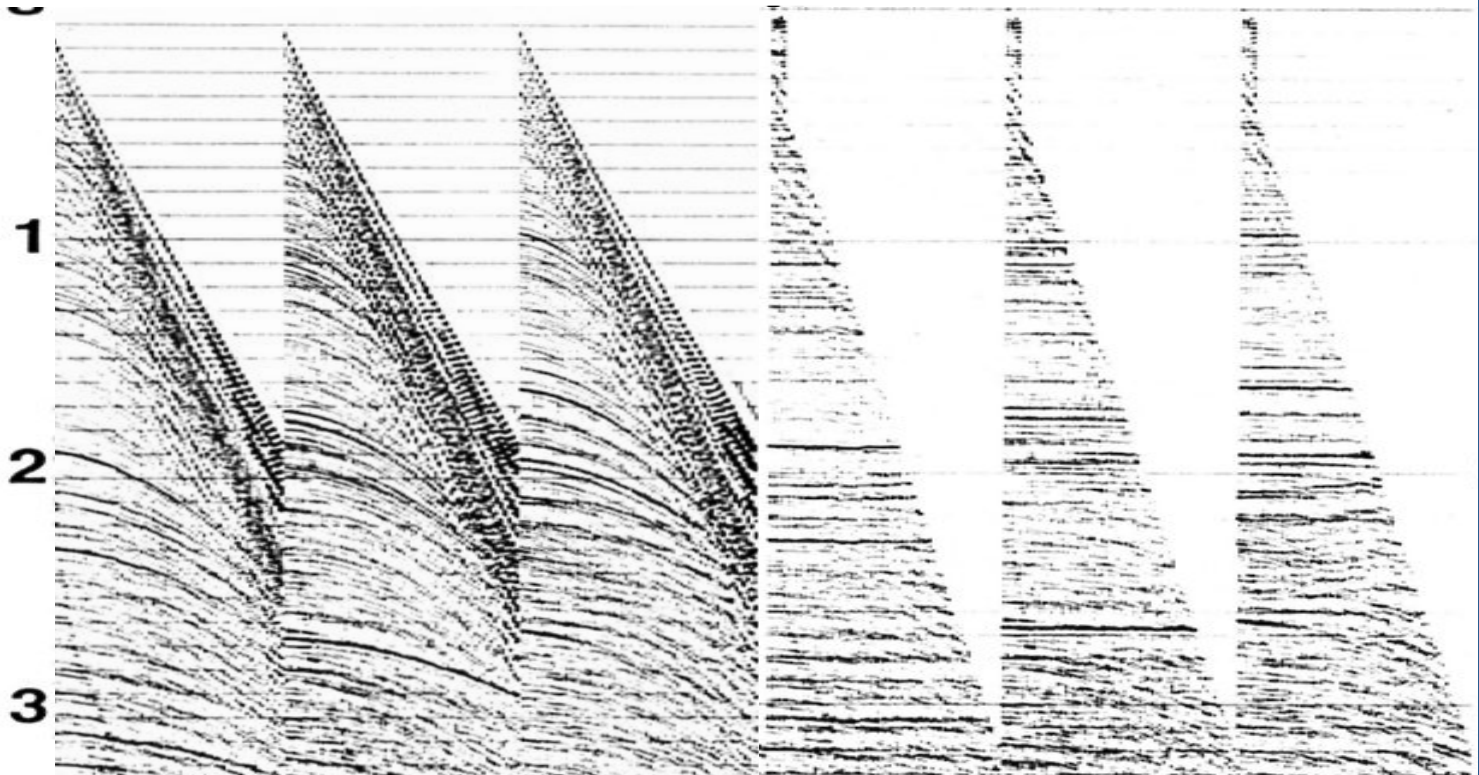


Simplified processing sequence:

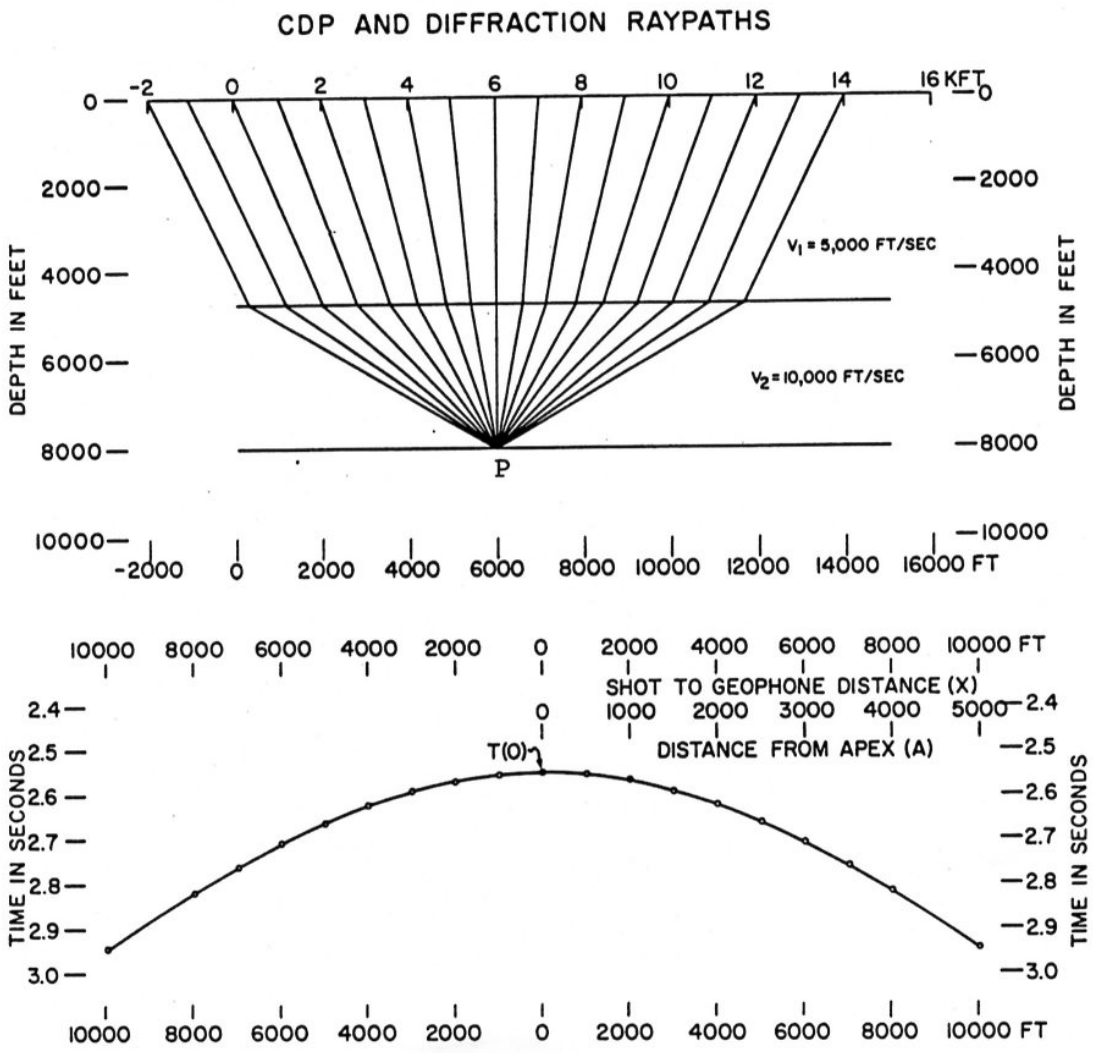
delete refracted energy

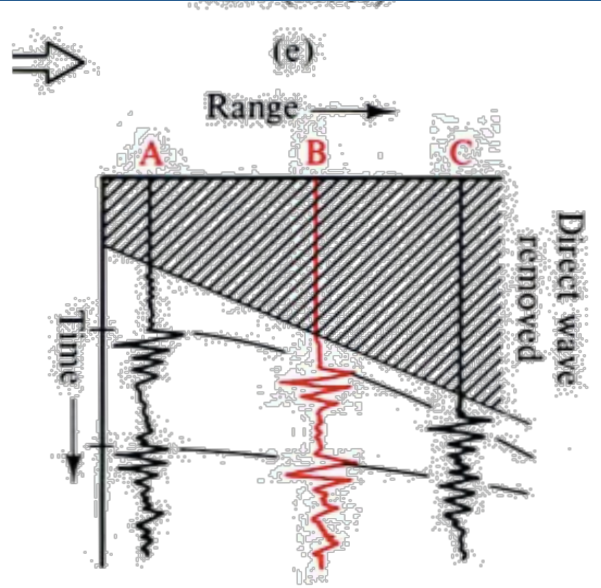
"mute"



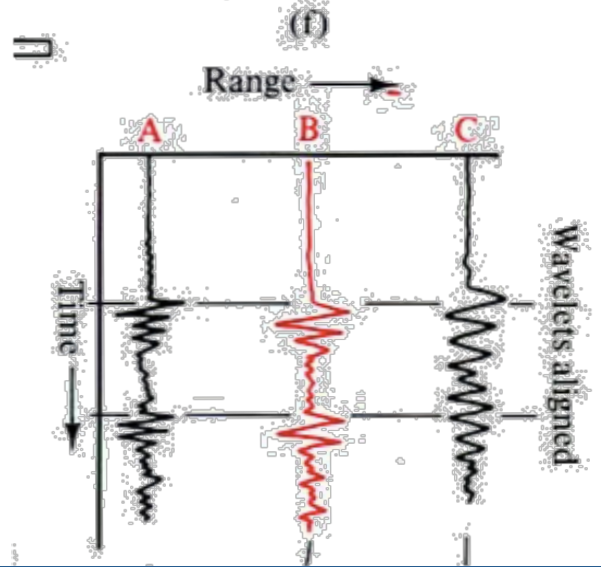


Simplified processing sequence:
correct for non-zero offset
"normal-moveout (NMO) correction"





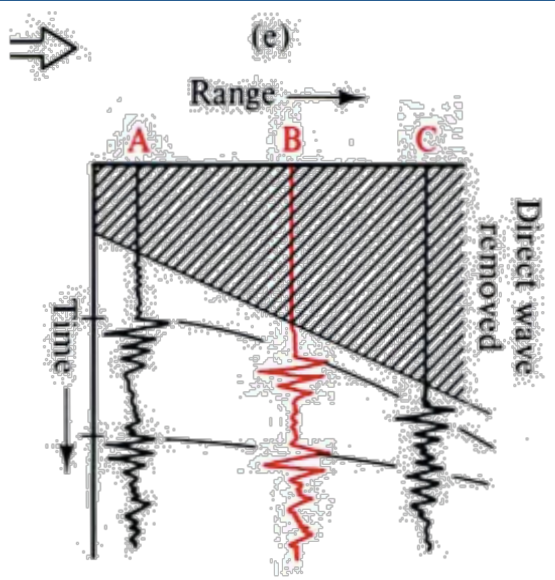
Correct travel-times for range-dependent delays



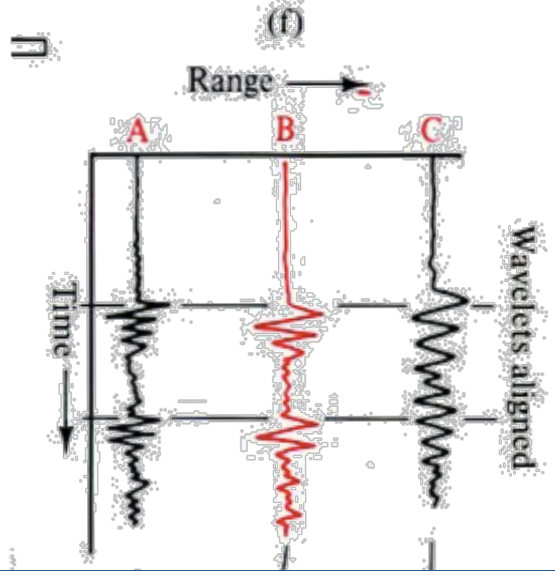
Simplified processing sequence:

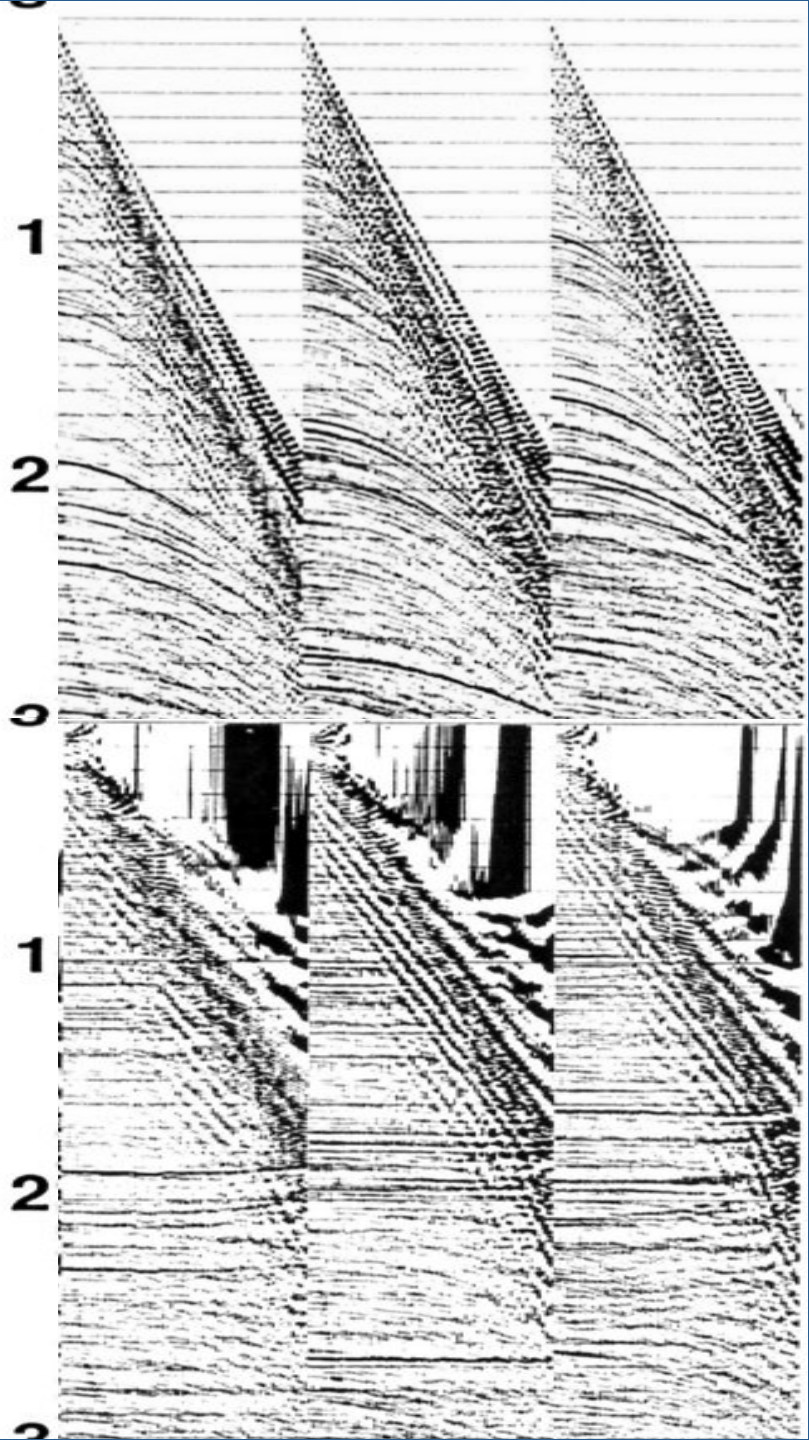
correct for non-zero offset

"normal-moveout (NMO) correction"



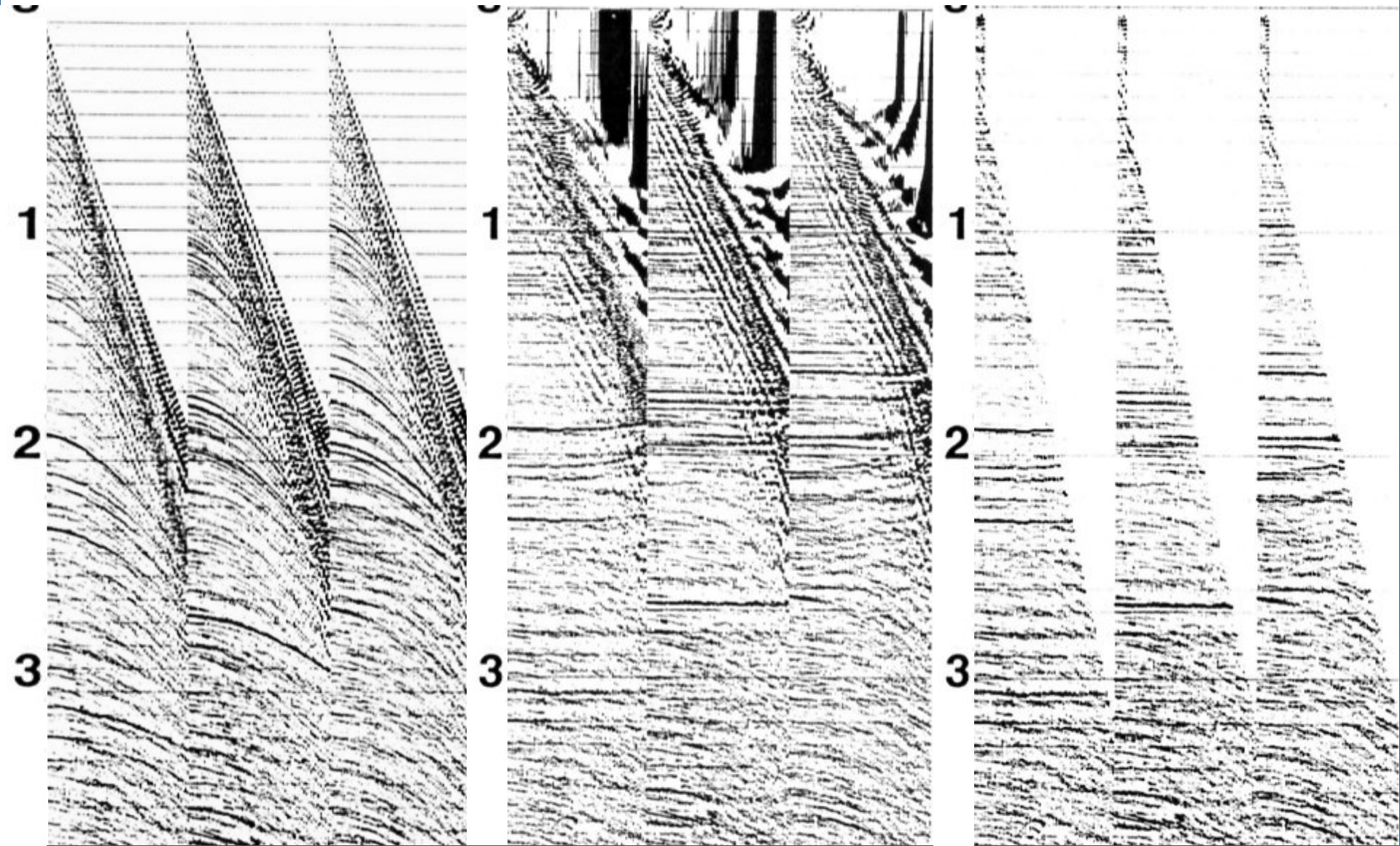
Correct travel-times for range-dependent delays





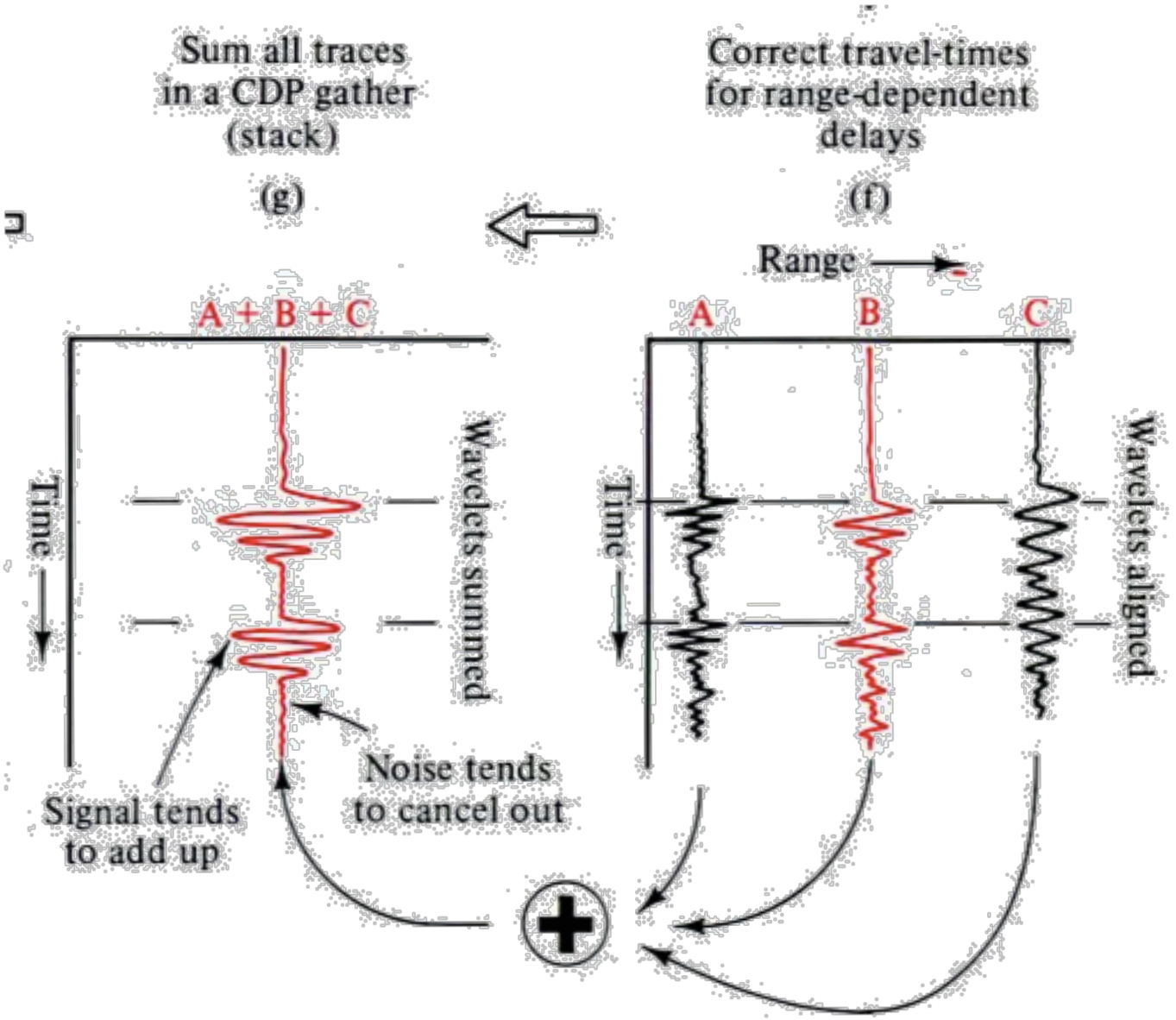
Sequence of processing can be varied:

in this case, ***NMO then mute***



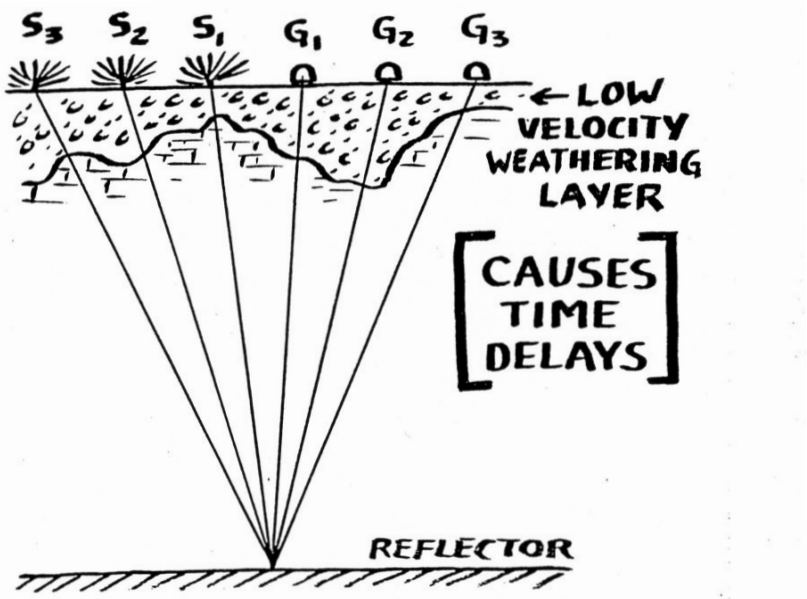
Simplified processing sequence: ***CMP stacking***

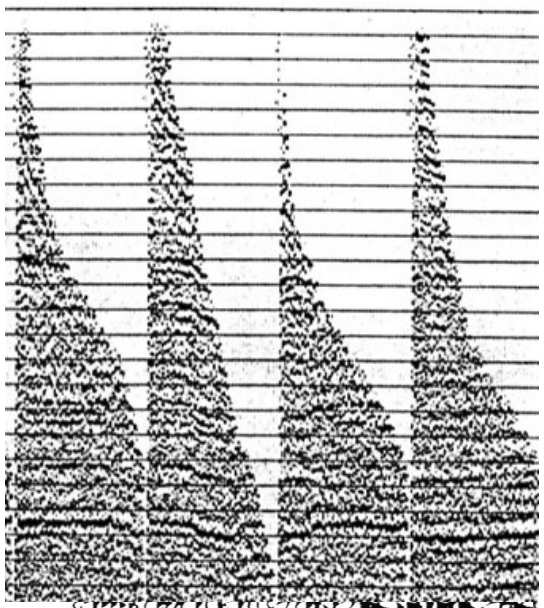
assumes all traces are appropriately corrected

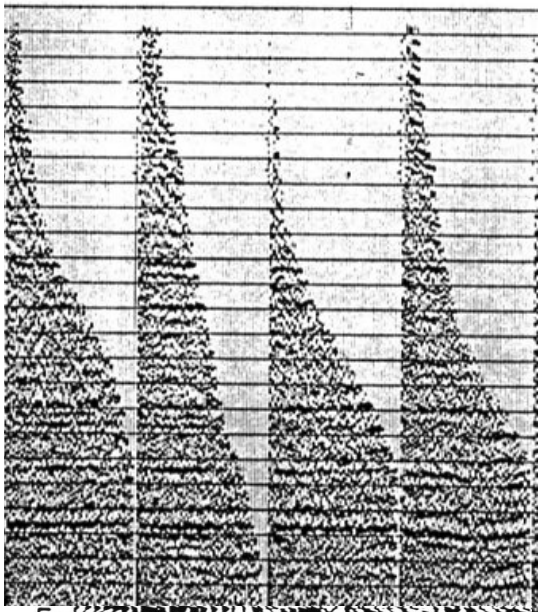


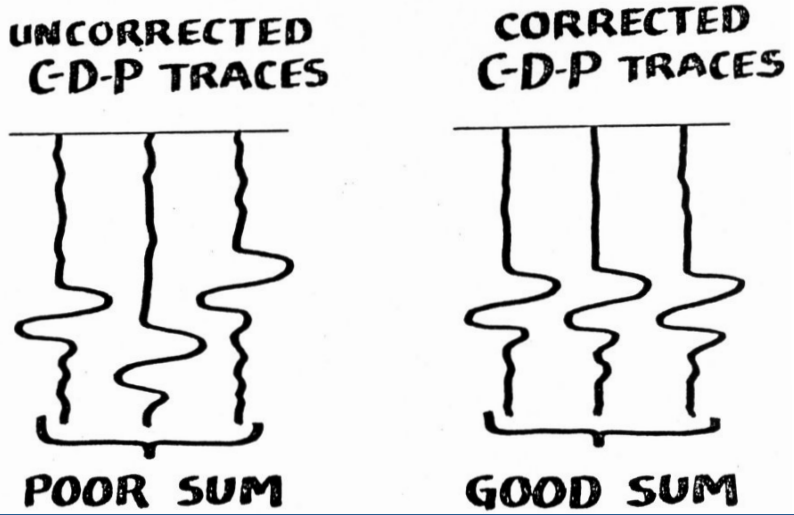
Simplified processing sequence: ***statics corrections*** *before CMP stacking*

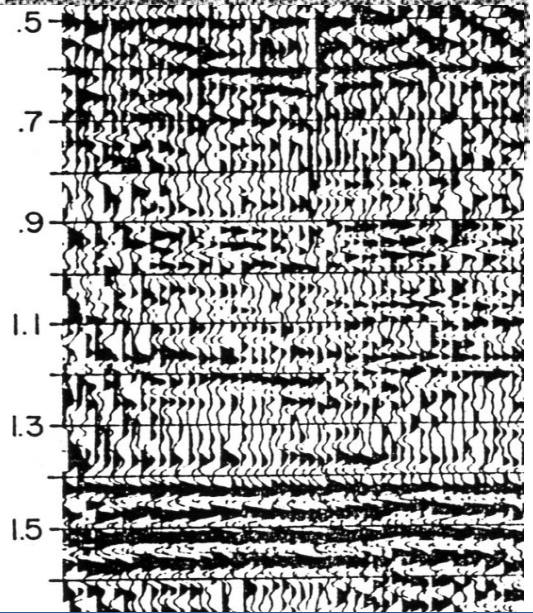
before ***after***

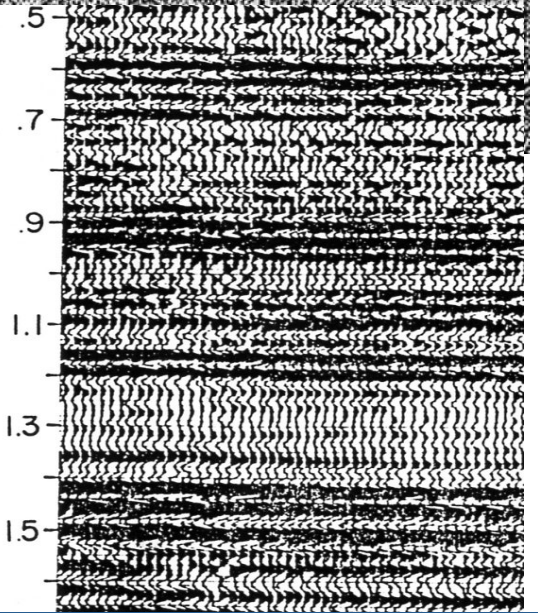




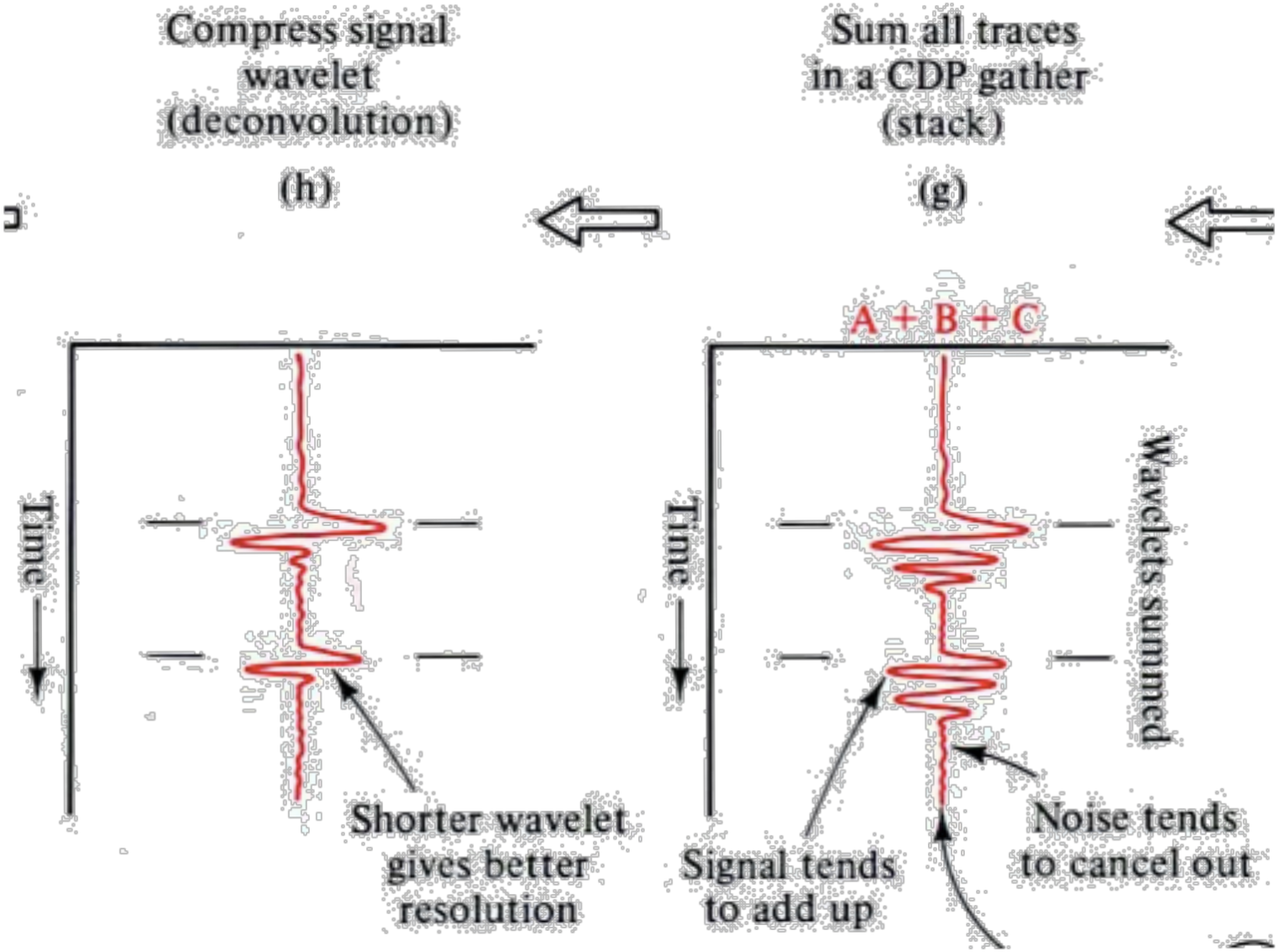




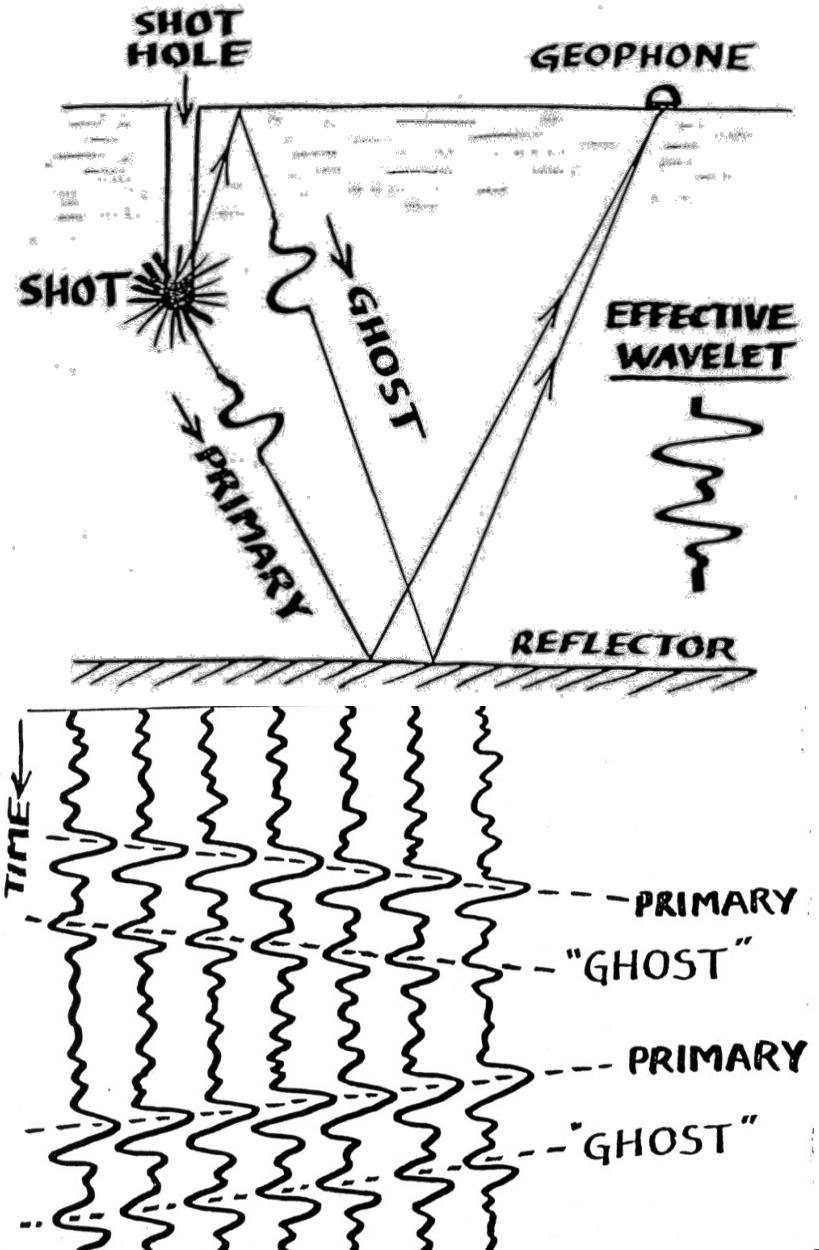




Simplified processing sequence: ***deconvolution***

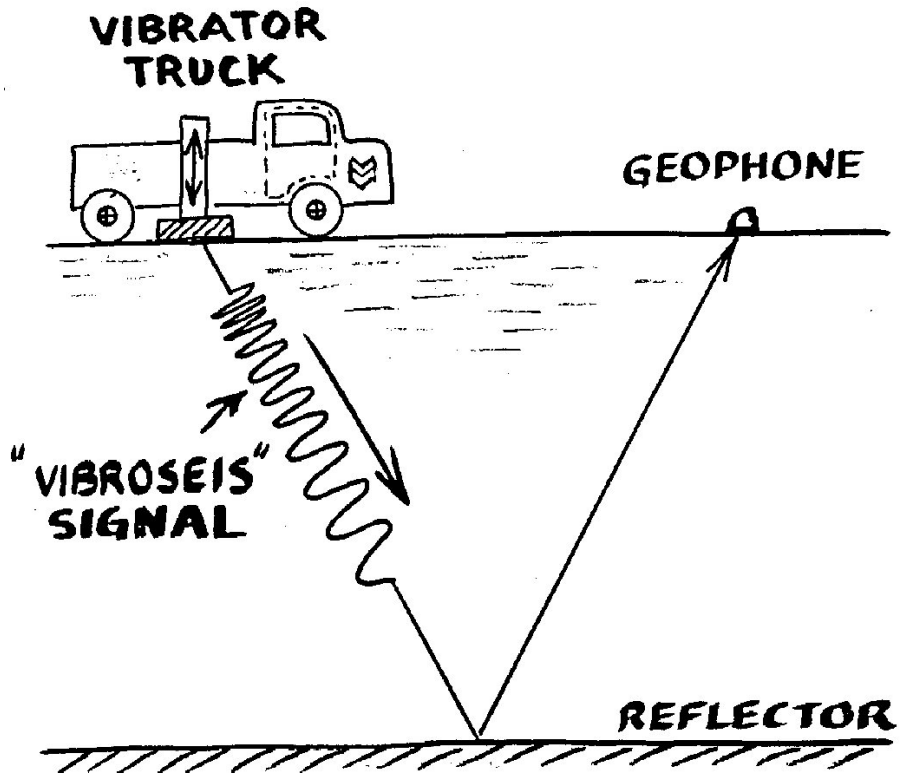


Causes of reverberative wavelet: acquisition



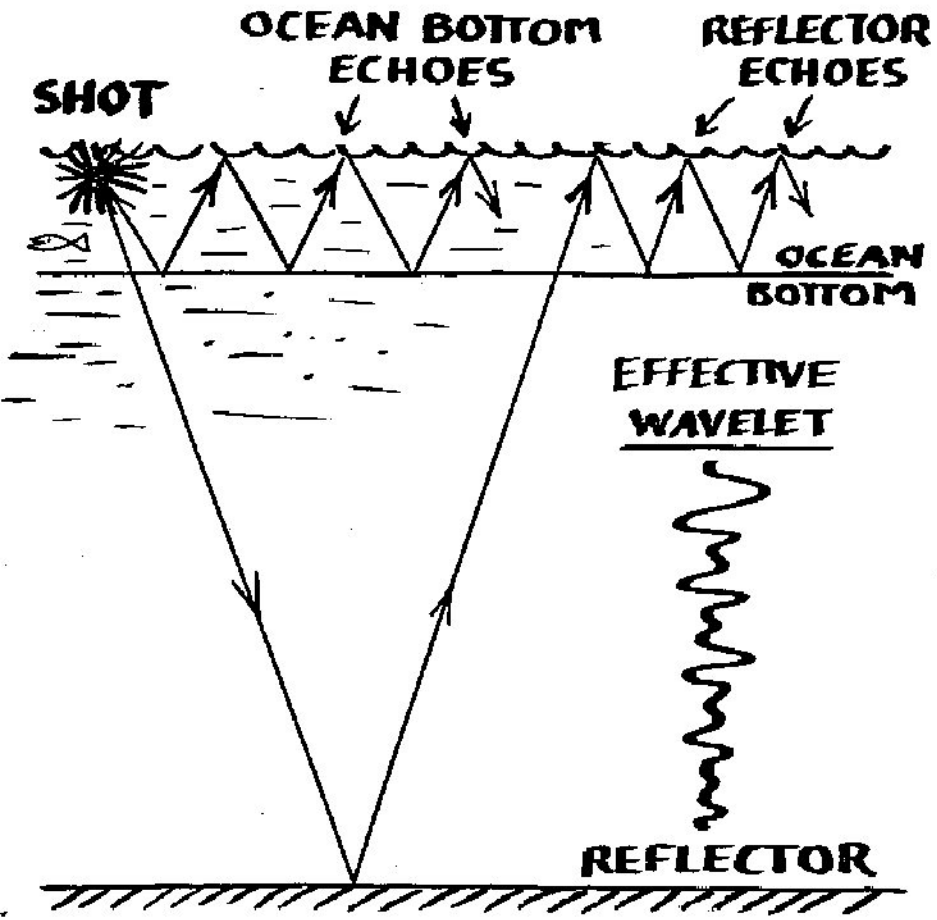
Dynamite / airgun

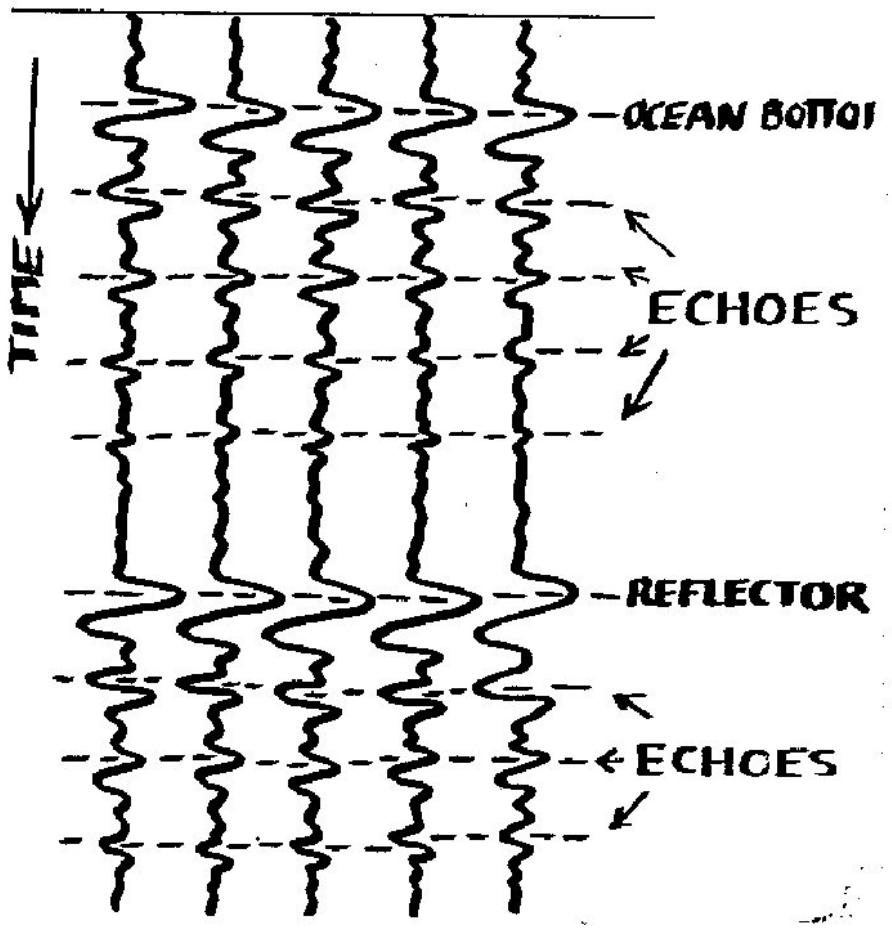
Vibroseis



Causes of reverberative wavelet: geology

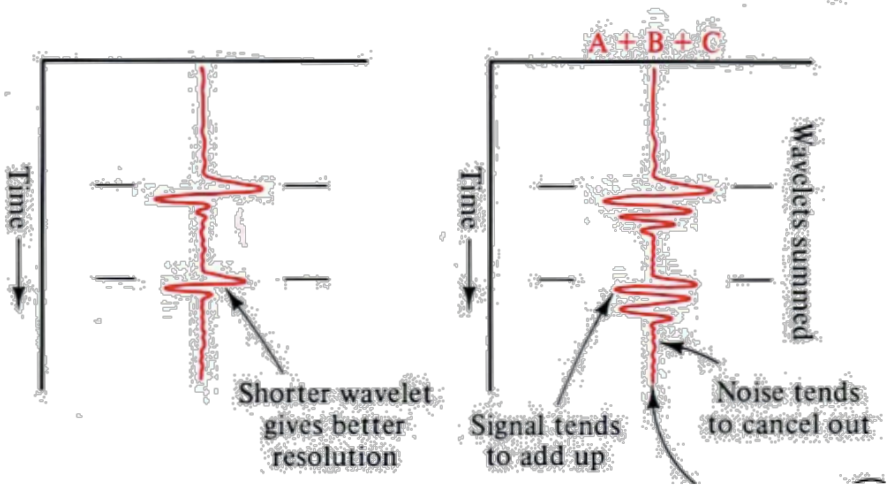
(water-bottom and peg-leg multiples)



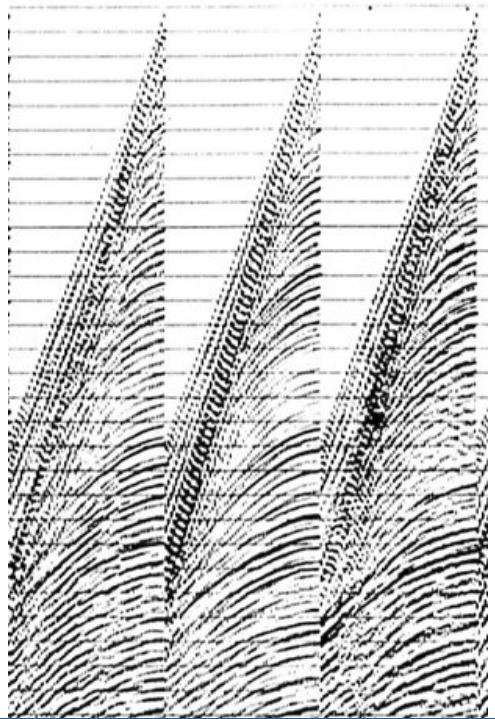


Simplified processing sequence:

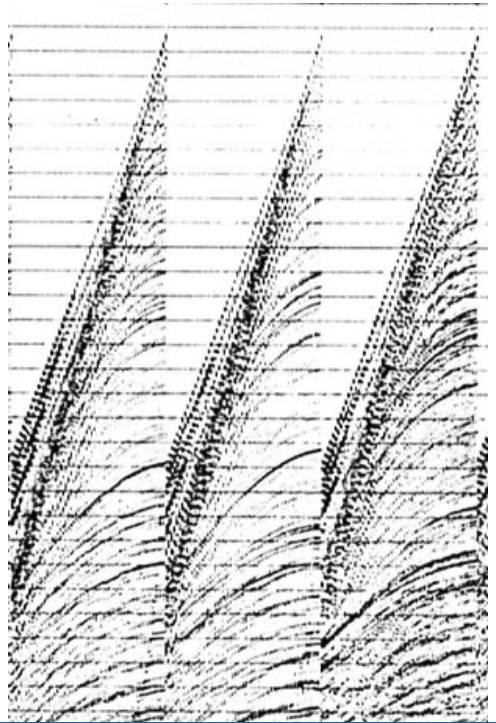
deconvolution



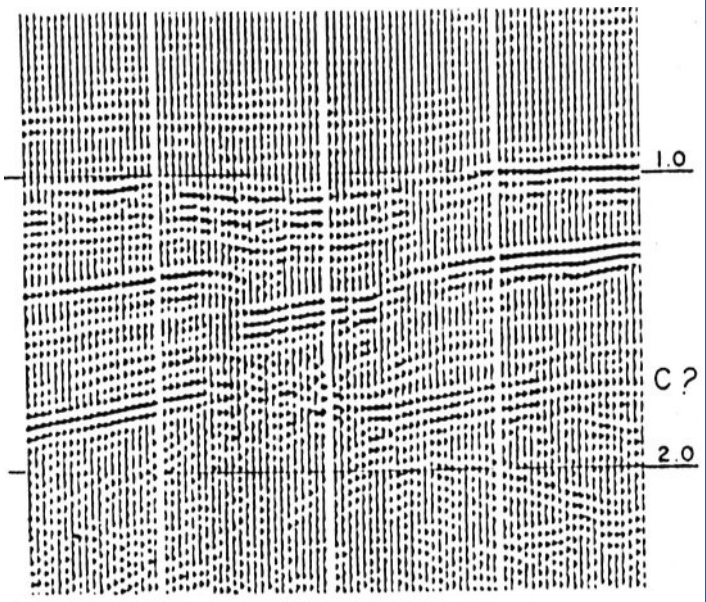
before



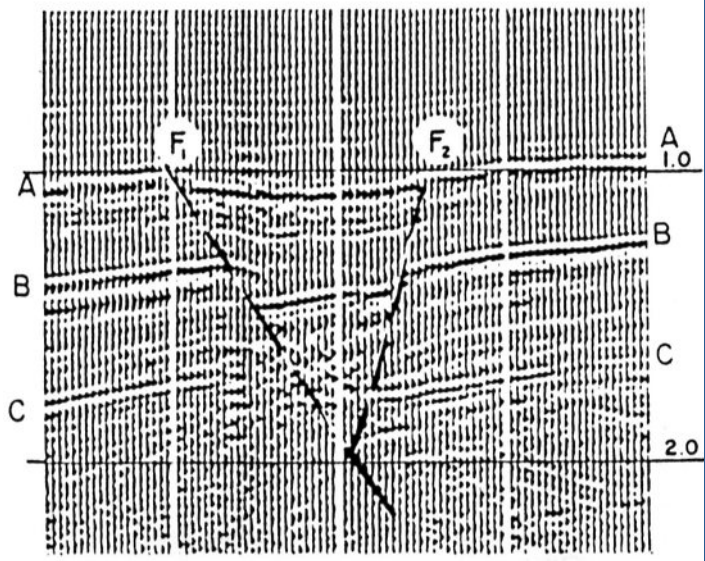
after



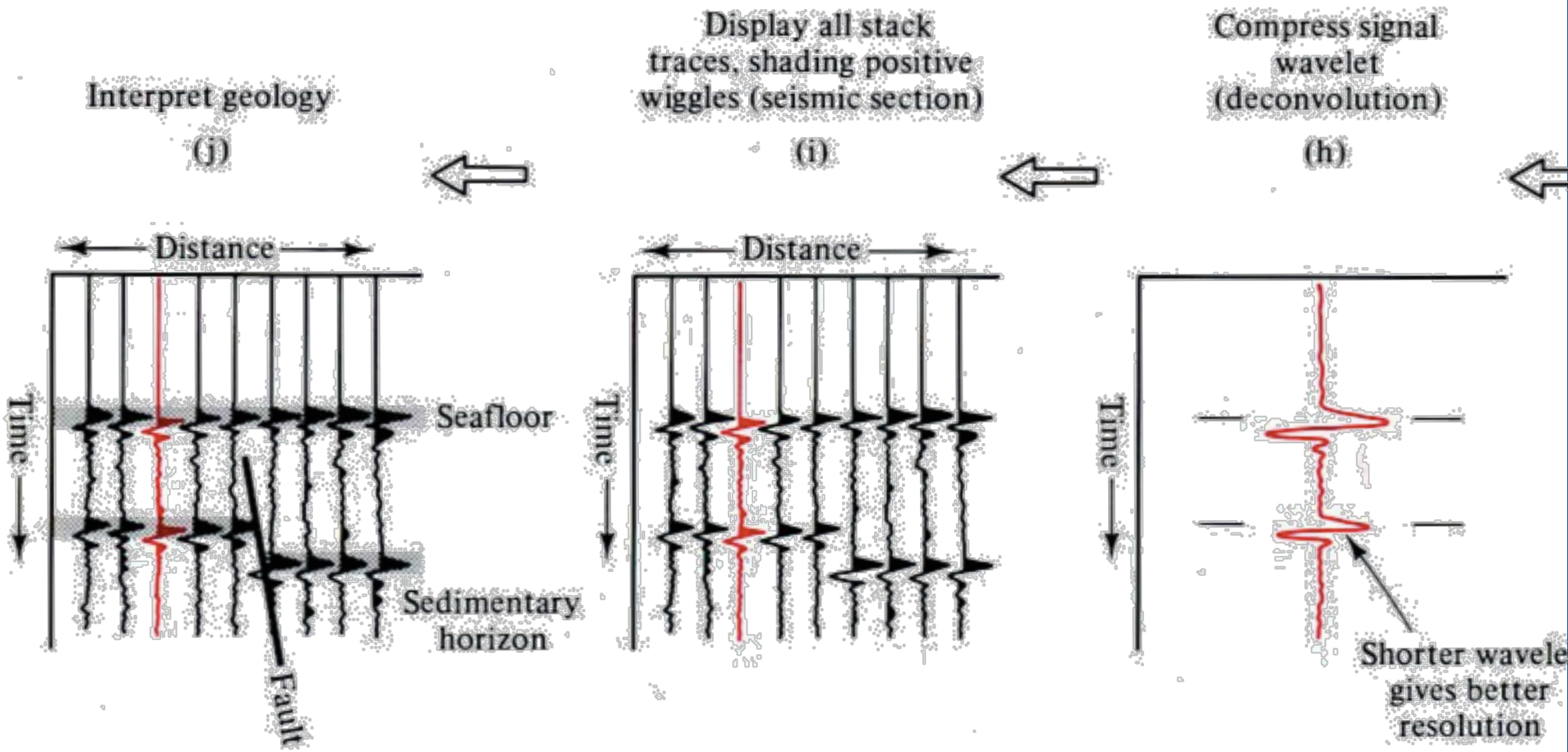
before



after

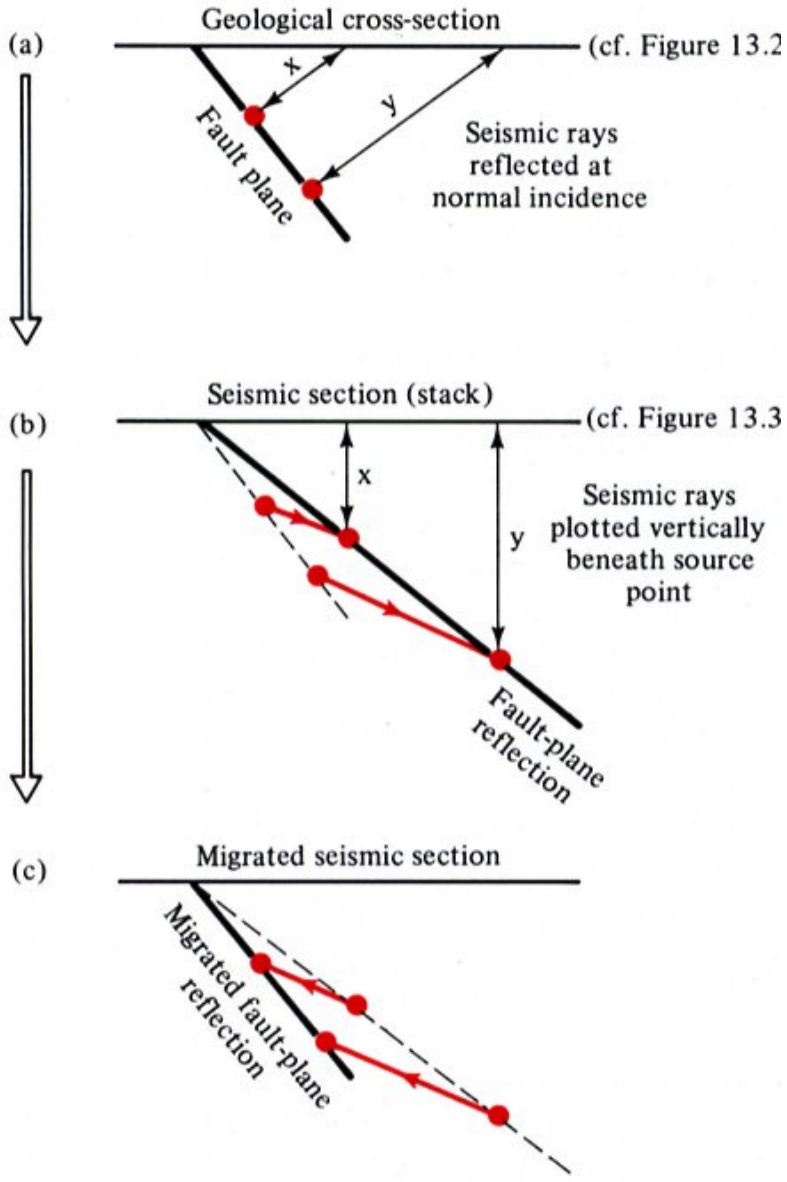


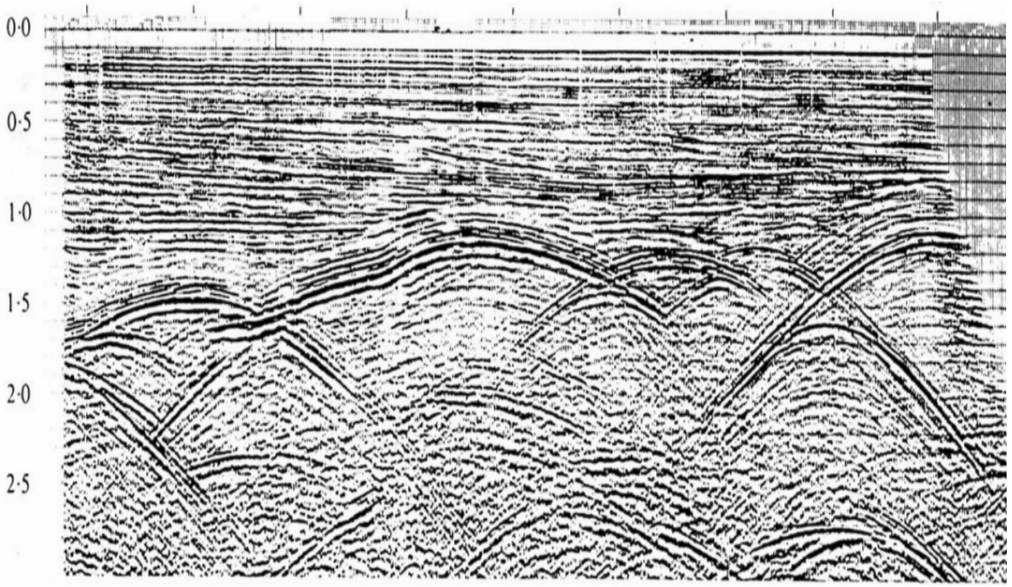
Simplified processing sequence: ***display and interpret***

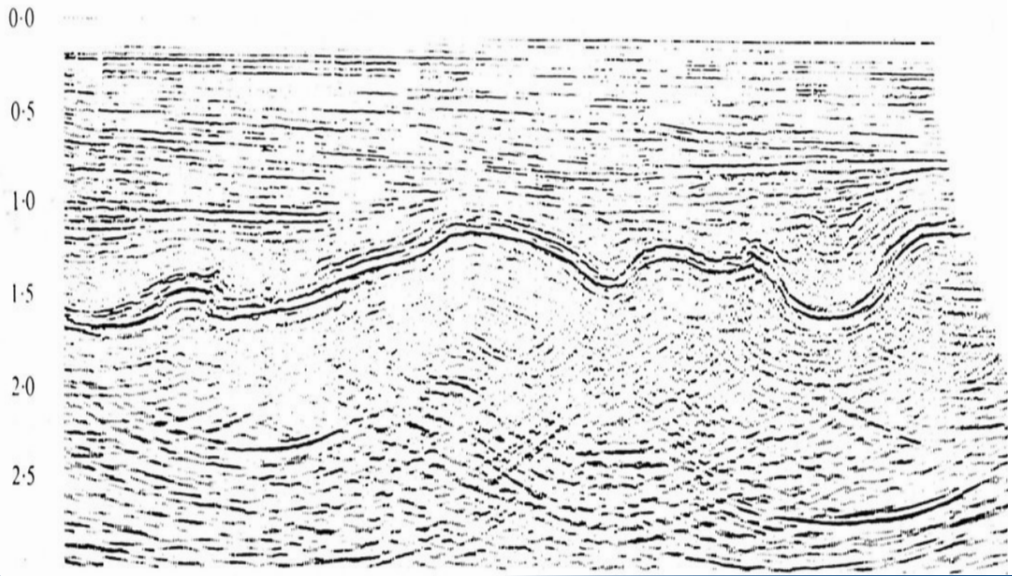


Simplified processing sequence:

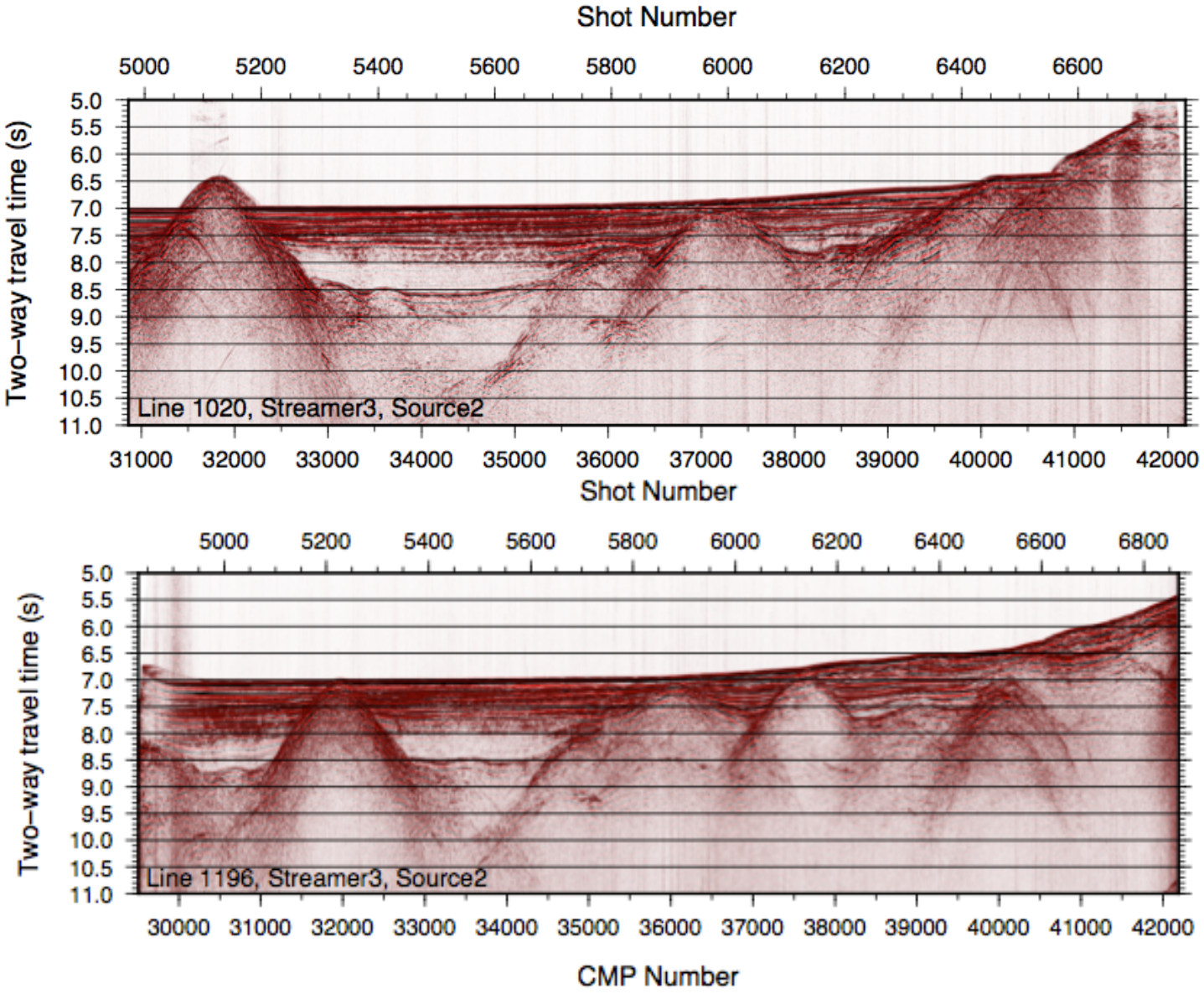
Migration: correctly re-positioning dipping layers in x-t



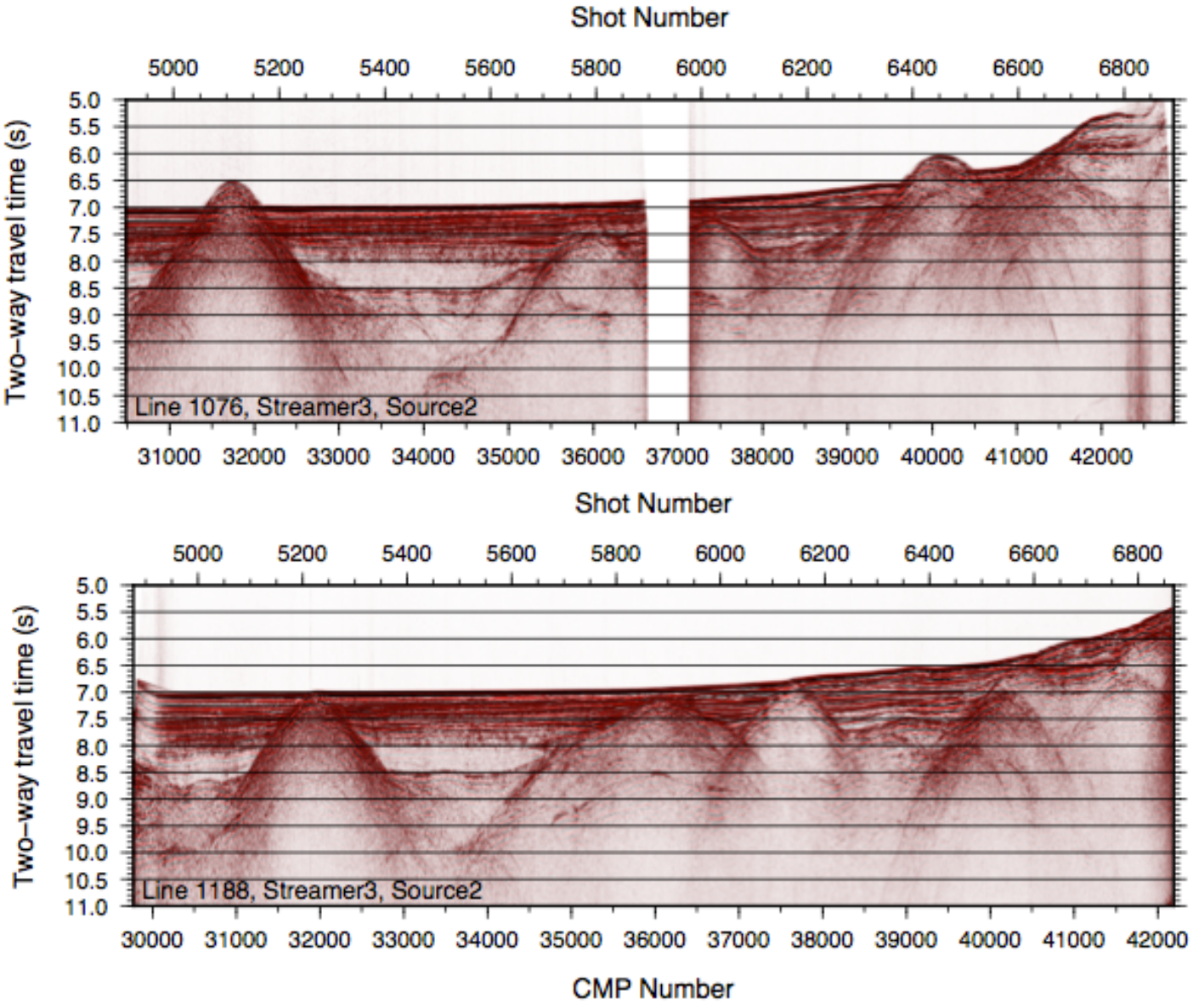




3-D brute stack seismic data: offshore NW Spain



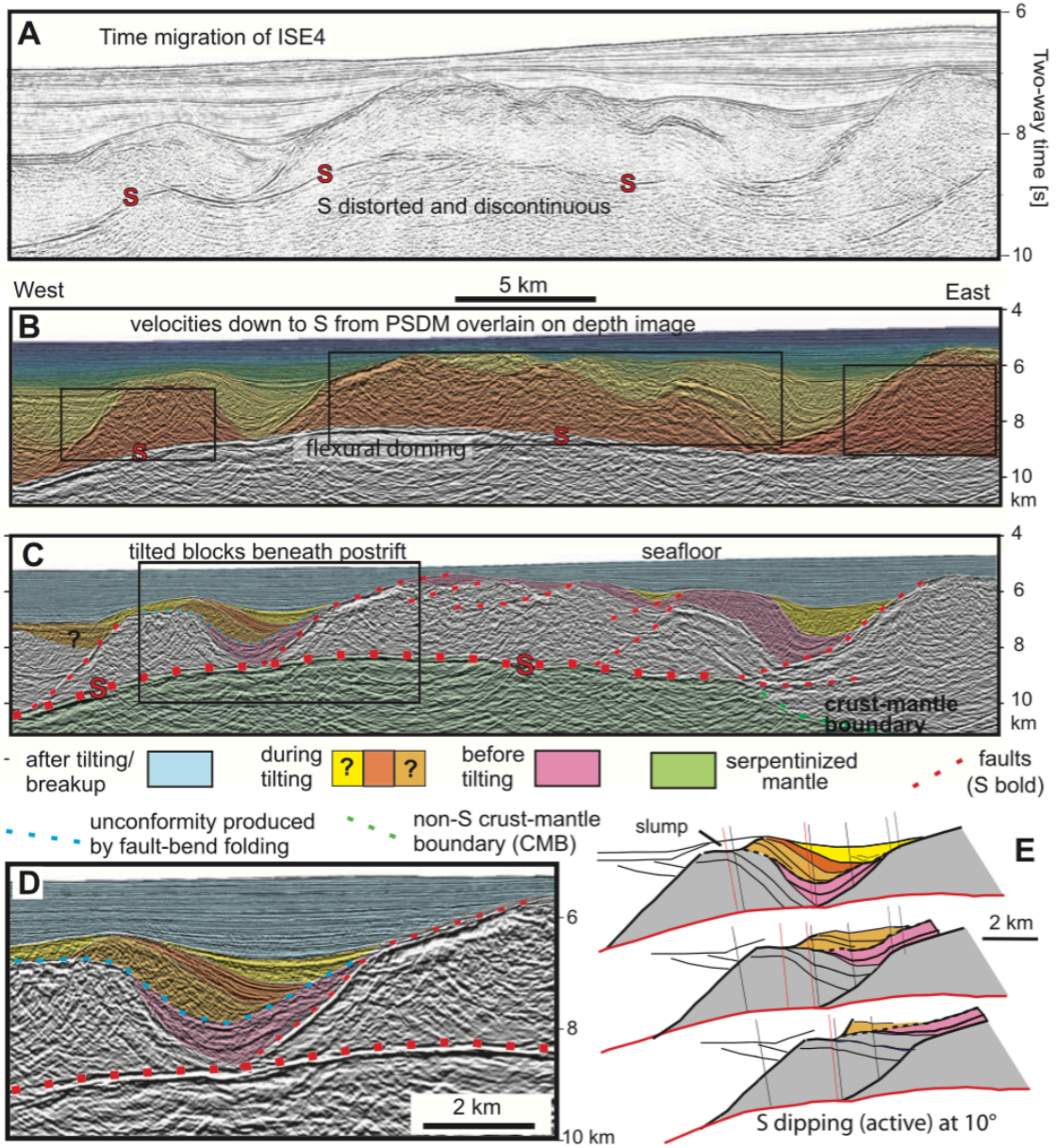
3-D brute stack seismic data: offshore NW Spain



Migration algorithms (from ProMax manual)

Migration Name	Category	Type	Velocity	V(x)	V(t/z)	Steep Dip	Run Time
Stolt 2D	F-K	Time	$V_{RMS}(x,t)$	Poor	Poor	Fair	0.2
Phase Shift 2D	Phase Shift	Time	$V_{INT}(x,t)$	None	Good	Good	1.0
Steep-Dip Explicit	F-D (70 deg)	Time	$V_{INT}(x,t)$	Fair	Good	Good	21.0
FD Time	(50 deg)	Time	$V_{INT}(x,t)$	Fair	Good	Fair	10.0
Fast Explicit FD Time	F-D	Time	$V_{INT}(x,t)$	Fair	Good	Fair	9.6
Explicit FD Depth	F-D	Depth	$V_{INT}(x,z)$	Good	Good	Good	21.7
Kirchhoff Depth	Kirchhoff/Im	Depth	$V_{INT}(x,z)$	Fair	Good	Good	7.3
		Depth	$V_{INT}(x,z)$	Good	Good	Good	12.0
	Explicit Mult. Arr.	Depth	$V_{INT}(x,z)$	Excel.	Excel.	Excel.	64.0
Kirchhoff Time	Kirchhoff	Time	$V_{RMS}(x,t)$	Fair	Good	Good	14.6
Reverse-Time T-K	Reverse Time	Time	$V_{INT}(t)$	None	Good	Good	2.5

Final interpreted reflection images: older data, same region offshore NW Spain



Reston et al., 2007

Questions?

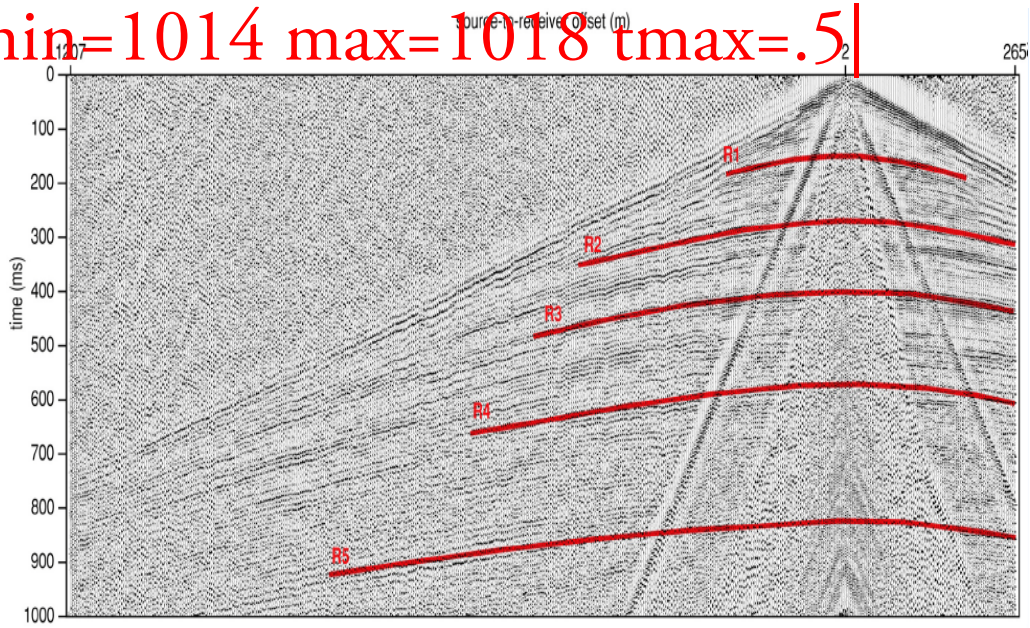
Sledgehammer shot viewing

- Read first 48 traces of segy file, define offset, and output SU file

```
segyread tape=BroncoStadium_shots.sgy | segyclean |suwind key=tracf min=1 max=48|sushw key=offset a=1 b=1 j=48 | sushw key=cdp a=1000 b=-1 c=2 j=48 >shots.su
```

- Select shots to view,

```
suwind < shots.su key=fldr min=1014 max=1018 tmax=.5| suxwigb perc=96 &
```



Slide from Lee Liberty

sushw/suchw

Examples:

1. set every dt field (sample rate) to 4ms

```
sushw < indata key=dt a=4000 |...
```

2. set the sx (source x position) field of the first 32 traces to 6400, the second 32 traces to 6300, decrementing by -100 for each 32 trace groups

```
...| sushw key=sx a=6400 c=-100 j=32 |...
```

3. set the offset fields of each group of 32 traces to 200,400,...,6400

```
...| sushw key=offset a=200 b=200 j=32 |...
```

4. perform operations 1., 2., and 3. in one call

```
..| sushw key=dt,sx,offset a=4000,6400,200 b=0,0,200 c=0,-100,0 j=0,32,32 |
```

5. Add 1000 to tracr value:

```
suchw key1=tracr key2=tracr a=1000 <infile >outfile
```

6. Set the receiver point (gx) field by summing the offset and shot point (sx) fields and then set the cdp field by averaging the sx and gx fields

```
suchw <indata key1=gx key2=offset key3=sx b=1 c=1|suchw key1=cdp key2=gx key3=sx b=1 c=1 d=2
>outdata
```

Slide from Lee Liberty

Reading header values from a binary file

To edit one or more header fields (as in geometry setting):

sugethw < sudata output=geom key=key1,key2 ... > hdrfile

Now edit the ASCII file hdrfile with any editor, setting the fields appropriately. Convert hdrfile to a binary format via:

a2b < hdrfile n1=nfields > binary_file

Then set the header fields via:

sushw < sudata infile=binary_file key=key1,key2,... > sudata.edited

Slide from Lee Liberty

Trace manipulation (suop)

- *Normalize traces*

suwind <shots.su key=mfldr in=1014 msuop ax=1018 |op=norm | suxwigb perc=90

- To reverse traces

suwind < *shots.su key=fldr min=1014 max=1018*| suop op=neg | suximage

- Type suop to see the range of trace manipulations
- Type suop2 to see the range of operations on 2 datasets

Slide from Lee Liberty

Trace muting

- MUTE above (or below) a user-defined polygonal curve with the distance along the curve specified by key header word
- Especially useful for land seismic data to remove surface waves (ground roll)

```
suwind < shots.su key=fldr min=1014 max=1018  tmax=.
2| sufilter f=30,60,300,500|sugain agc=1 wagc=.05 |
sumute key=offset xmute=1,48 tmute=.01,.14 mode=1 |
suxwigb perc=96
```

Slide from Lee Liberty

Velocity Analysis

suvelan – semblance velocity analysis

suwind <cdps.su key=cdp min=1000 max=1000 tmin=5| suvelan fv=1400 | suximage f2=1400 d2=50 mpicks=velout.txt

or

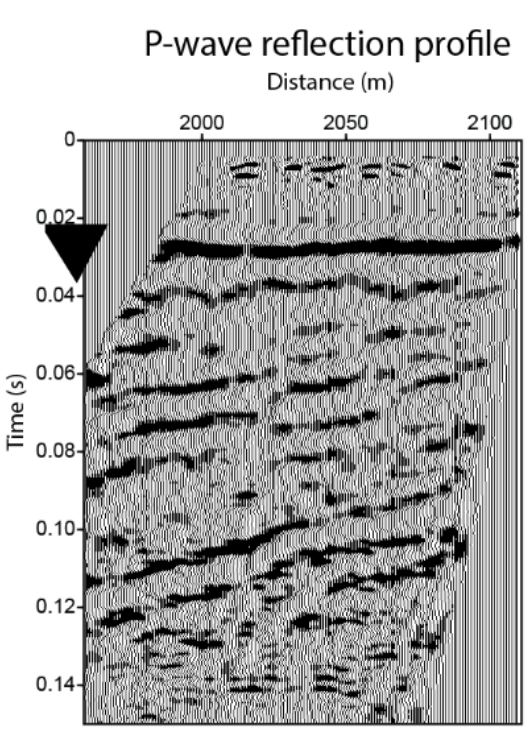
Constant velocity **stacks** via normal moveout (NMO) corrections

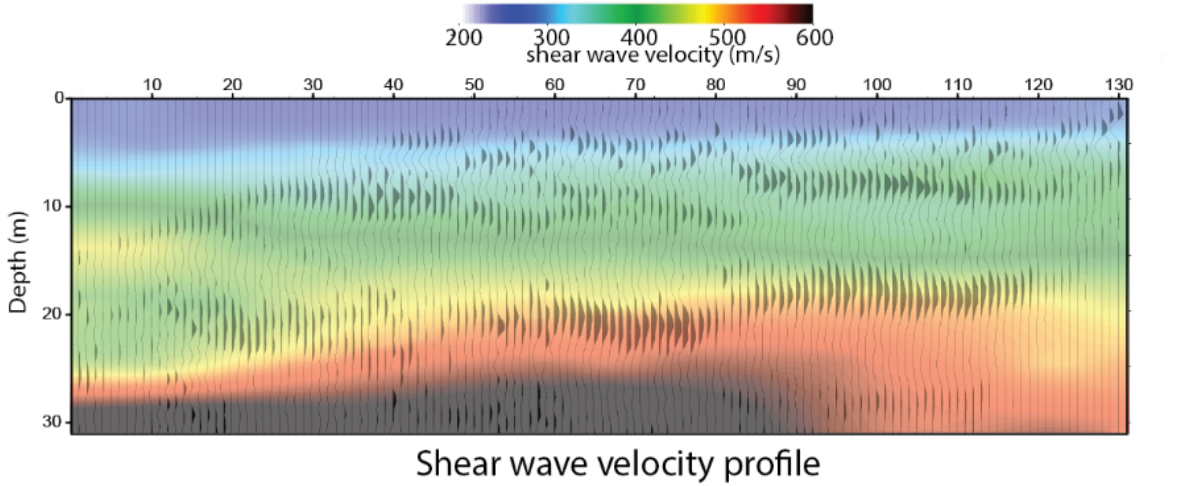
suwind <cdps.su tmax=.15| sufilter f=30,50,300,500 |sugain agc=1 wagc=.05 |sumute key=offset xmute=1,48 tmute=.01,.14 mode=1| sunmo tnmo=0 vnmo=1500 | sustack |suxwigb perc=96

Slide from Lee Liberty

Poststack Phase shift migration cdp data

```
suwind <cdps.su tmax=.15| sufilter f=30,50,300,500 |sugain agc=1 wagc=.05 |sumute key=offset xmute=1,48 tmute=.01,.14 mode=1|
sunmo tnmo=0 vnmo=1500 | sustack |
sumigps dx=1. vmig=1500| suxwigb perc=96
```

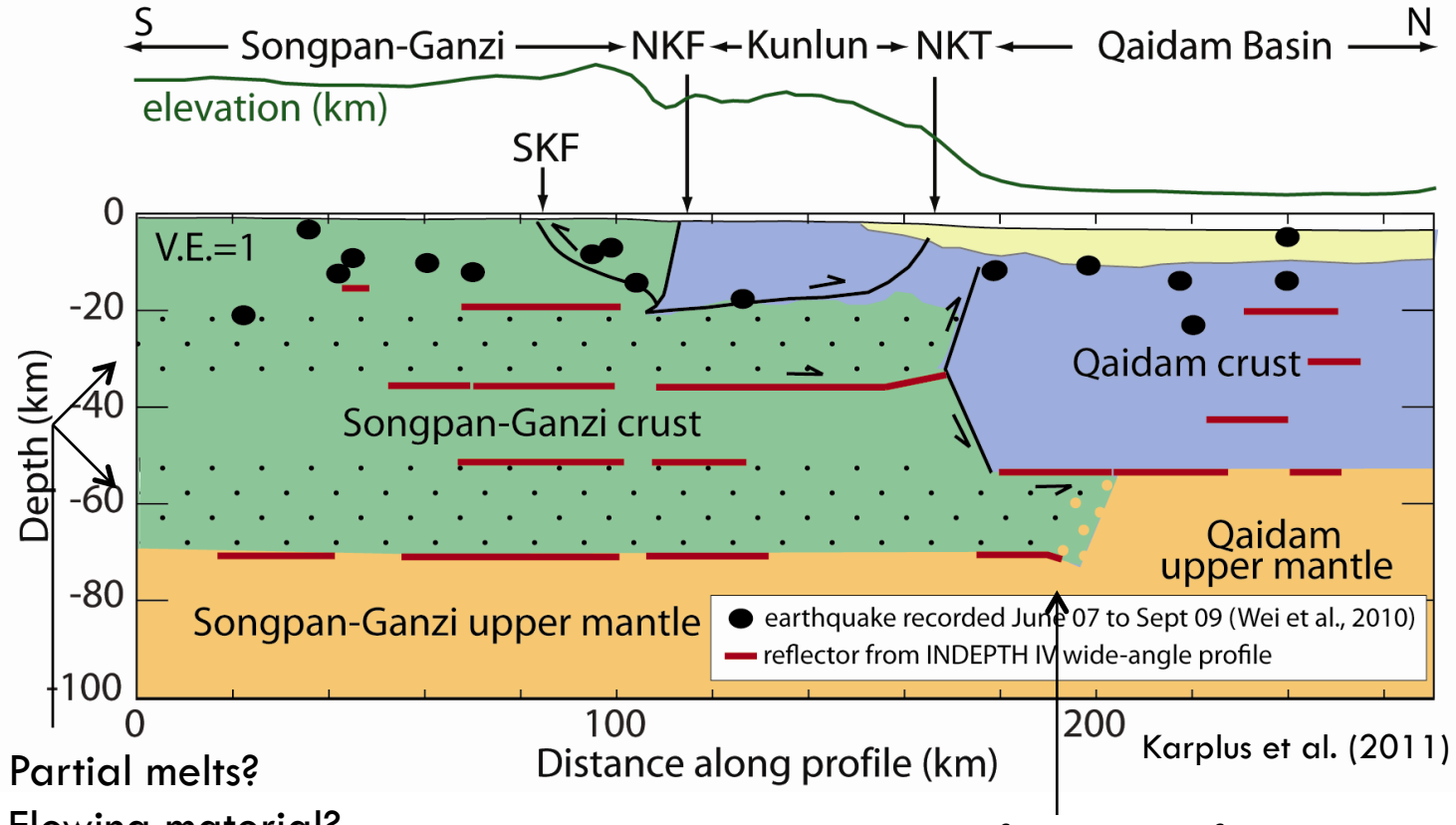




Shear wave velocity profile

Slide from Lee Liberty

Summary: new crustal structure of the Kunlun-Qaidam boundary



Partial melts?

Flowing material?

Location of transition from thicker to thinner crust