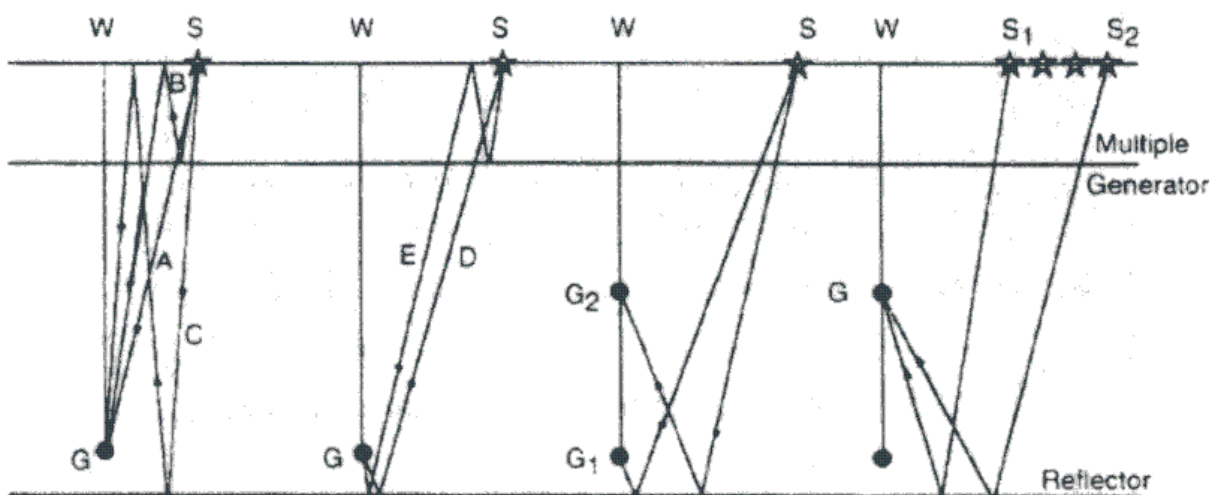


Vertical Seismic Profiling (VSP)

- VSP types
 - Planning and Acquisition
 - Processing
 - VSP to CMP transformation
-
- Reading:
 - Sheriff and Geldart, Section 13.4

Types of VSP

- By placing geophones in a borehole, favourable recording conditions are achieved:
 - Shorter paths;
 - Lower attenuation, higher frequencies;
 - Less effects of weathering;
 - Receiver spread may run across the horizon of interest.



Zero-offset

Offset

Walkaway

Objectives of VSP surveys

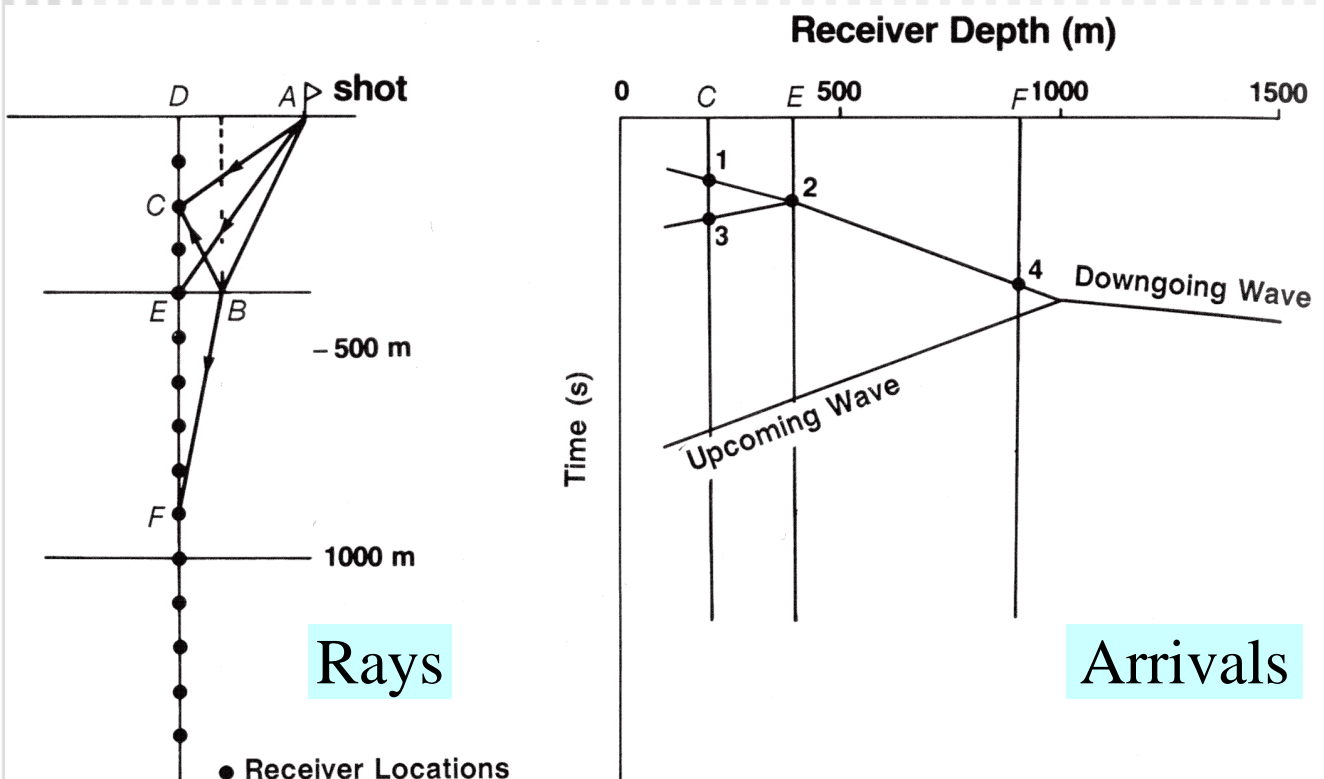
Table 13.1 *Objectives of VSP surveys*

Objective	How achieved
Reflector identification	Upgoing wave studies on zero-offset VSP
Surface-to-borehole correlation	
Increased resolution at depth	
Time-depth conversion	First-break studies on zero-offset VSP
Enhanced velocity analysis	
Log calibration	
Multiple identification	Downgoing wave studies on zero-offset VSP
Deconvolution operator	
Improve poor data area	All types, especially offset VSP
Predict ahead of bit	Upgoing wave studies on zero-offset VSP
Structural imaging	Walkaway or offset VSP with presurvey modeling
Delineate salt dome	Proximity survey with source over dome
Seeing above/below bit on deviated wells	Zero-offset, offset, or walkaway VSP
Stratigraphic imaging (channels, faults, reefs, pinchouts)	Multiple-source locations with offset VSP
AVO studies	Research study on offset VSP with presurvey modeling
P/S-wave analysis	Research study on offset VSP, three-component phone
Polarization studies	
Fracture orientation	
Attenuation analysis	Research study on zero-offset VSP
Secondary recovery	Research study on offset VSP
Tomographic studies	Multiple wells, multiple offsets
Permeability studies	Tube-wave analysis research study

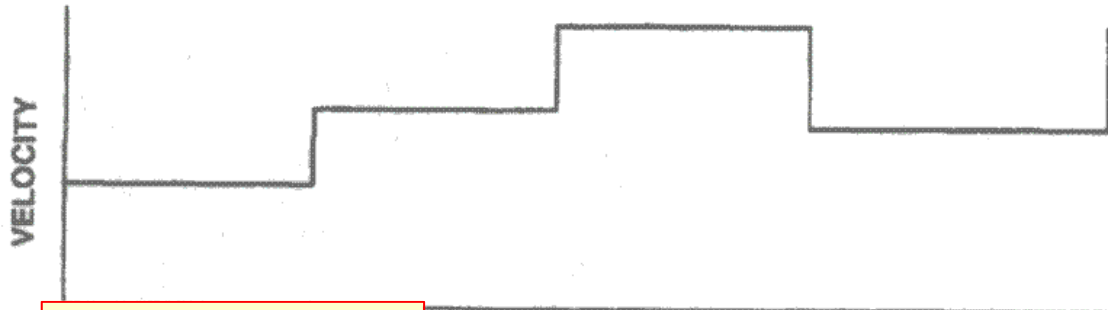
After Gilpatrick and Fouquet, 1989.

VSP travel times

- *Downgoing* and *upgoing* waves can be directly observed and isolated.
- To transform reflection times into *vertical-incidence times*, two steps are performed:
 - "VSP static correction" - mapping of time ABC into ABC + CD. For zero-offset VSP, time CD simply equals the observed time AC;
 - For offset VSP, NMO correction maps time ABC into DEC and AC into DC.

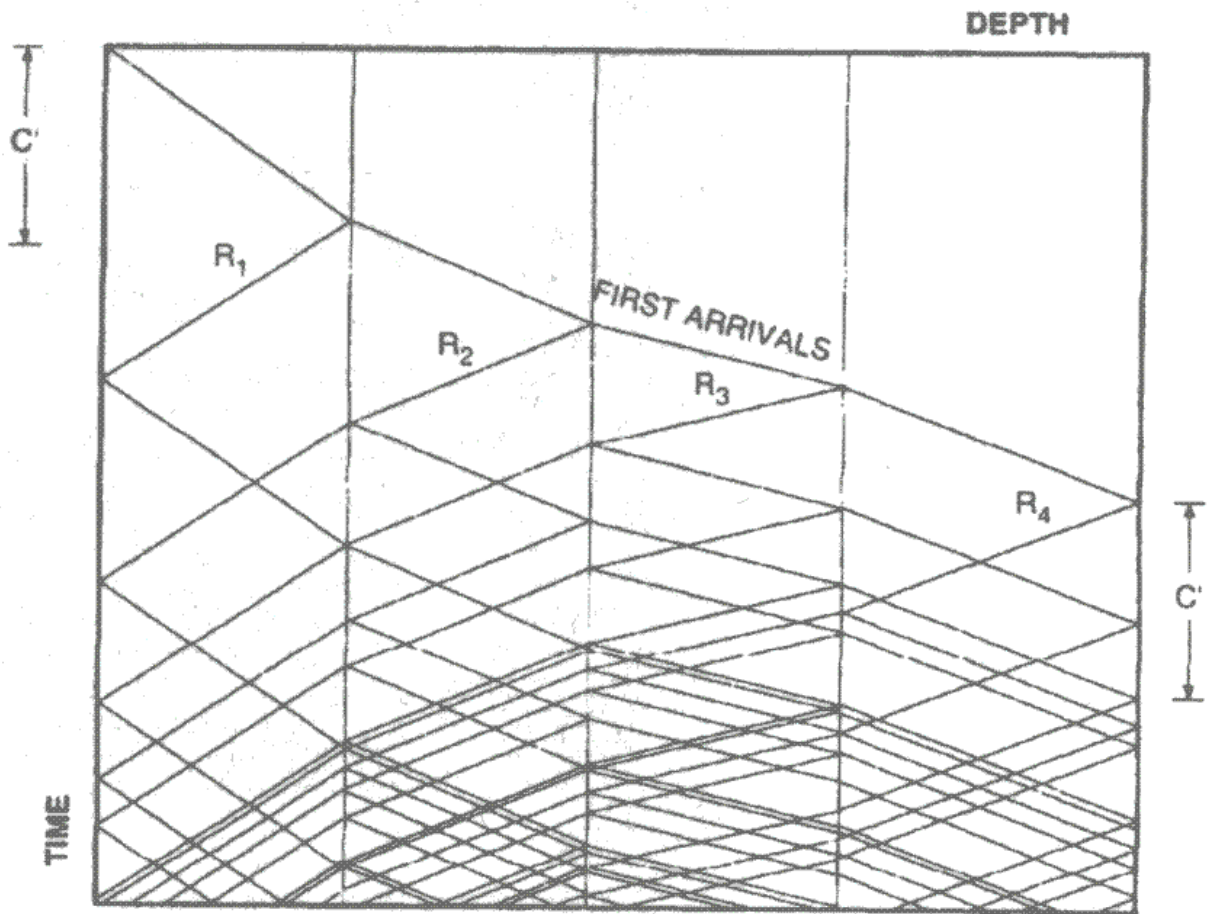


Multiple reflections in a VSP section



This region is relatively free from intrabed multiples

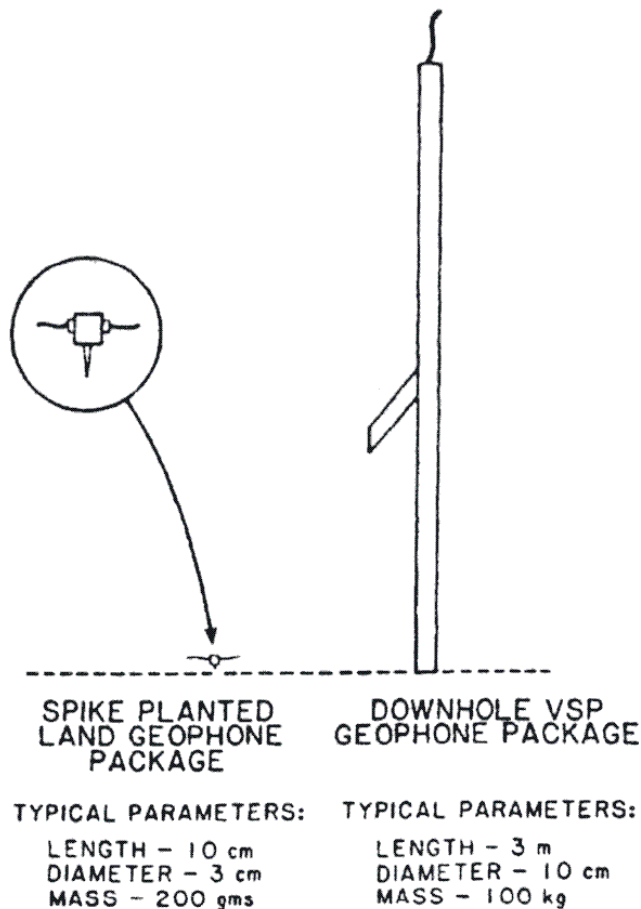
(a)



(b)

Surface vs. VSP geophone

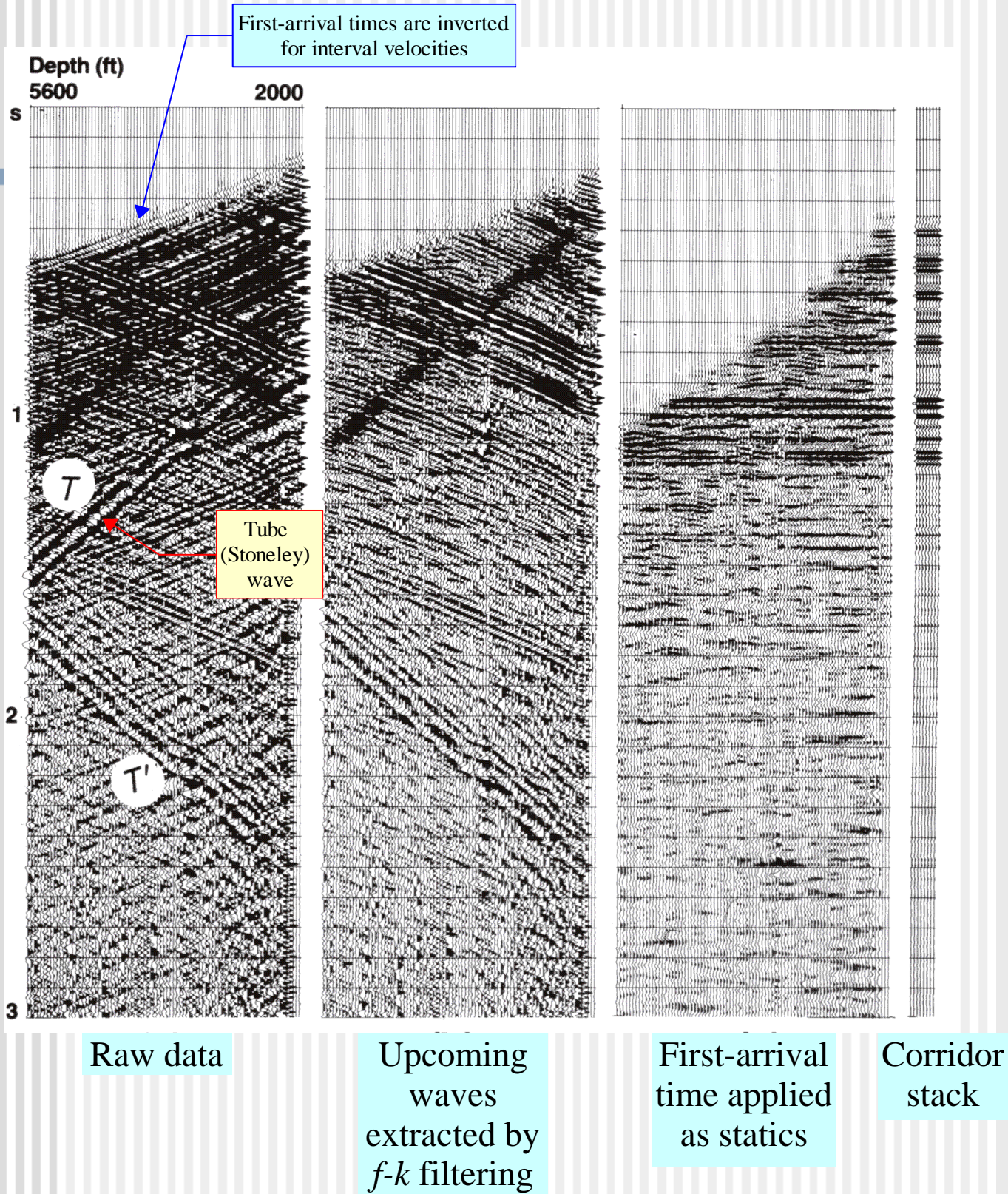
- VSP sonde should usually:
 - be 3-component; contain several levels;
 - include a retractable anchoring device;
 - contain orientation gear (a gyro);
 - withstand temperatures, pressures and fluids.



Acquisition procedure

- Make sure tool depth=0 at the well head;
- Slack the cable after anchoring;
- Record 5-6 levels as the tool is being lowered;
- Determine the gain and number of records to stack for required Signal/Noise;
- Take at least 5 records and monitor quality at every level;
- Reoccupy the down levels and check the depth and waveforms;
- Avoid washed out zones;
- Recheck depth at well head.

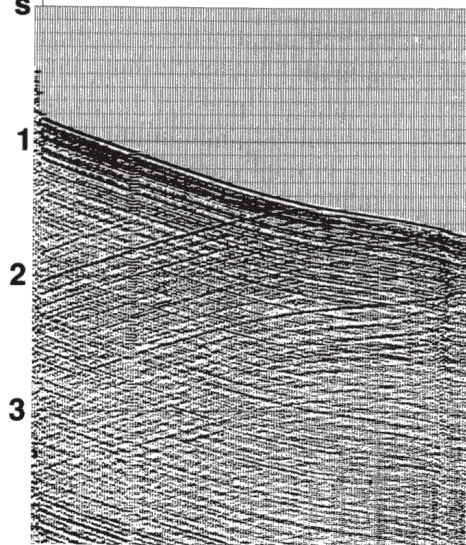
VSP data processing



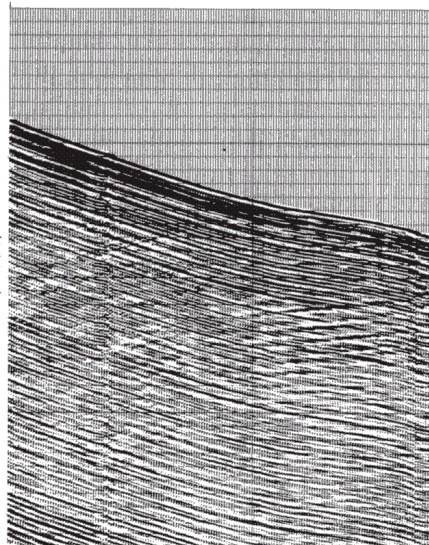
VSP data processing

another example

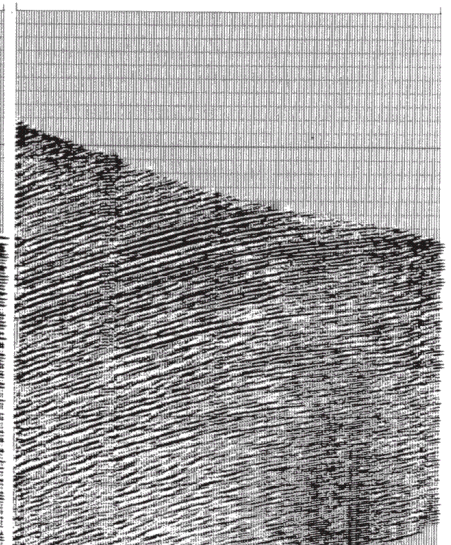
5110 Depth (ft) 12256



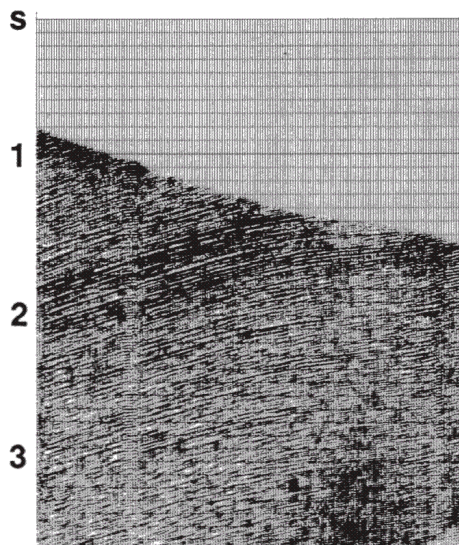
Raw



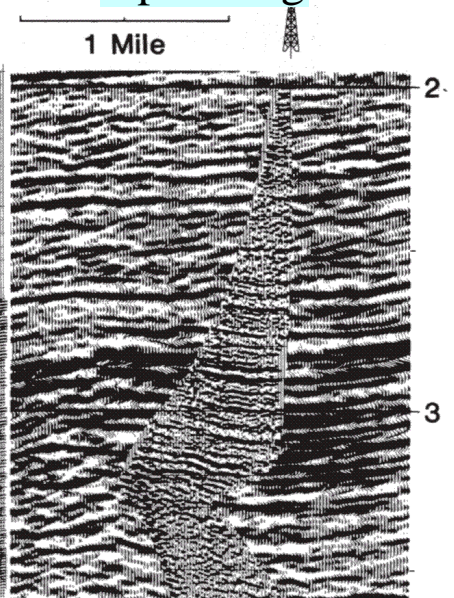
Downgoing



Upcoming



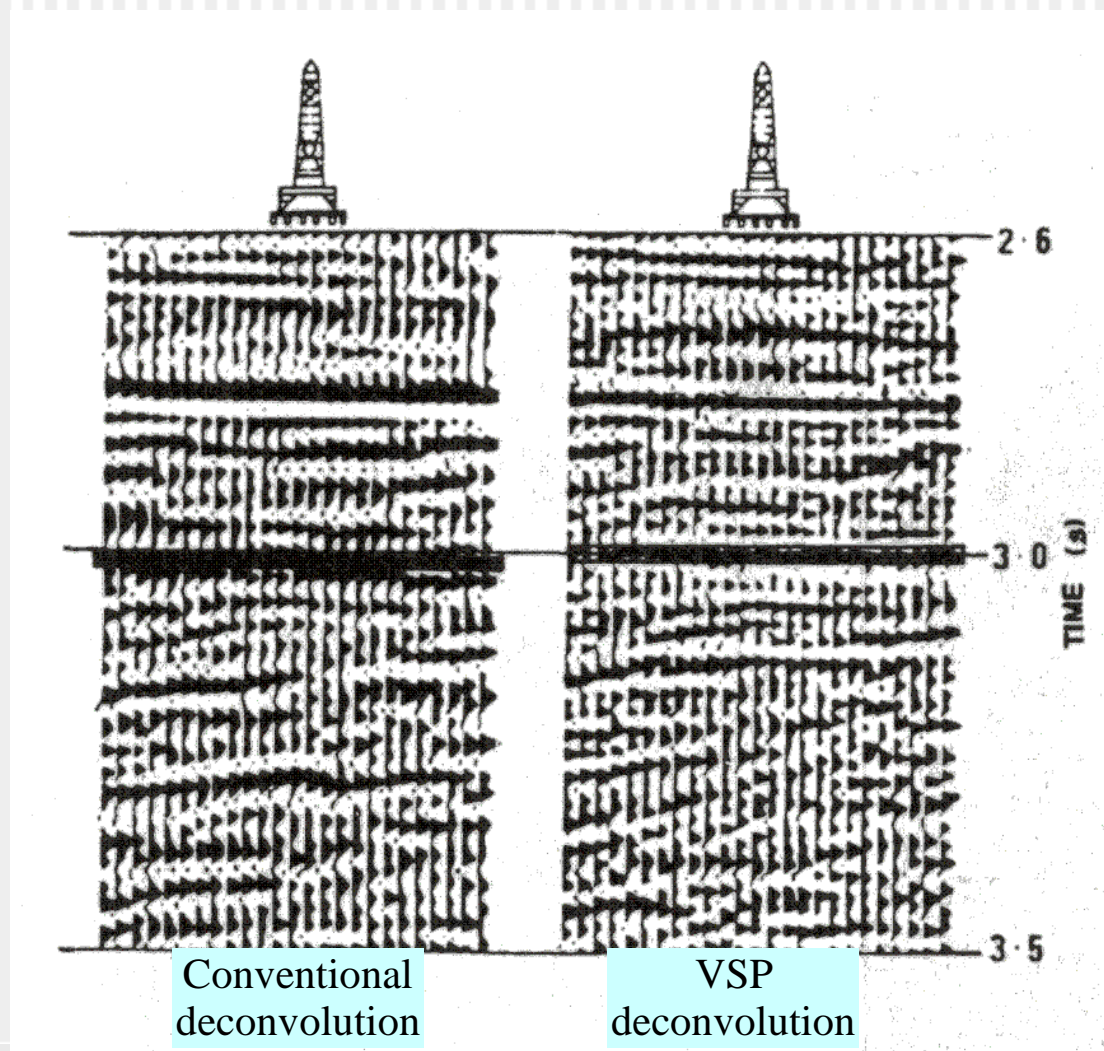
Deconvolved



Combined with CMP

VSP deconvolution

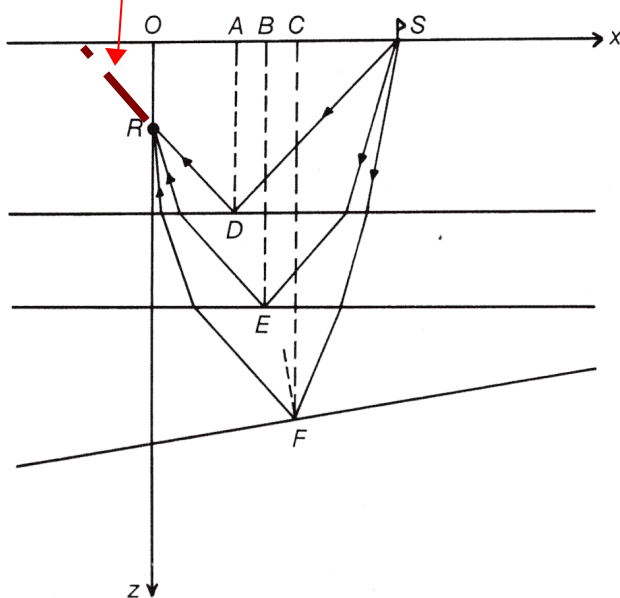
- Deconvolution filters derived from VSP can be applied to CMP data across the same area
- Because of broader frequency band and better-quality VSP recording, this deconvolution improves CMP data:



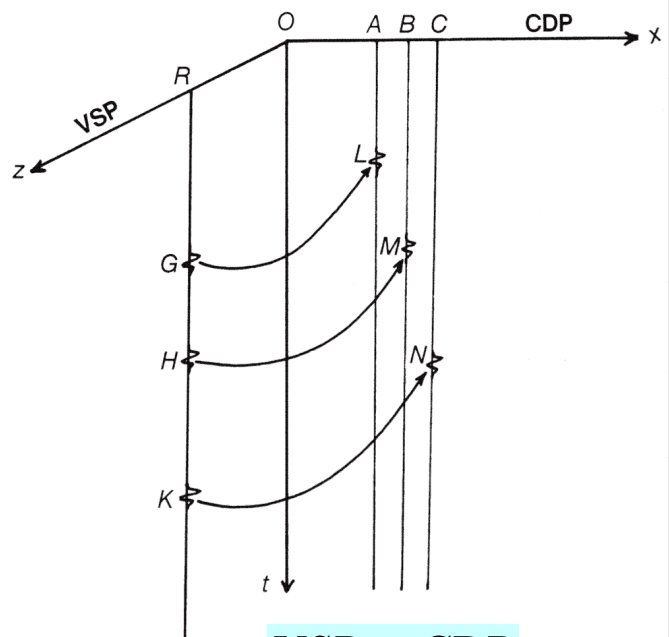
VSP migration and VSP to CMP transform

- VSP reflection sections are often transformed into CMP-like sections that would be obtained using geophones placed on the surface
 - Travel times are extended by the extra time from the borehole geophone to the surface
 - Travel times are mapped into depth via ray tracing;
- VSP apertures are limited, and so we need to know the dominant dips or use other constraints

To transform a VSP to surface reflection, we need to add the time along this ray



Rays



VSP to CDP
transform