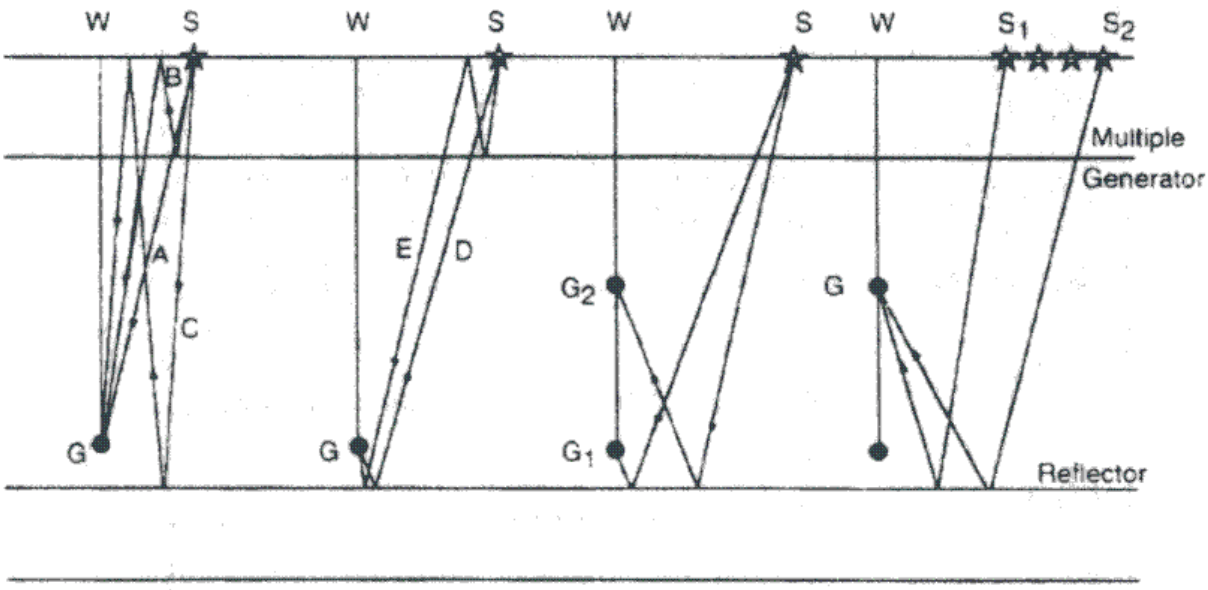
Vertical Seismic Profiling

- VSP types
- Planning and Acquisition
- Processing

- 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

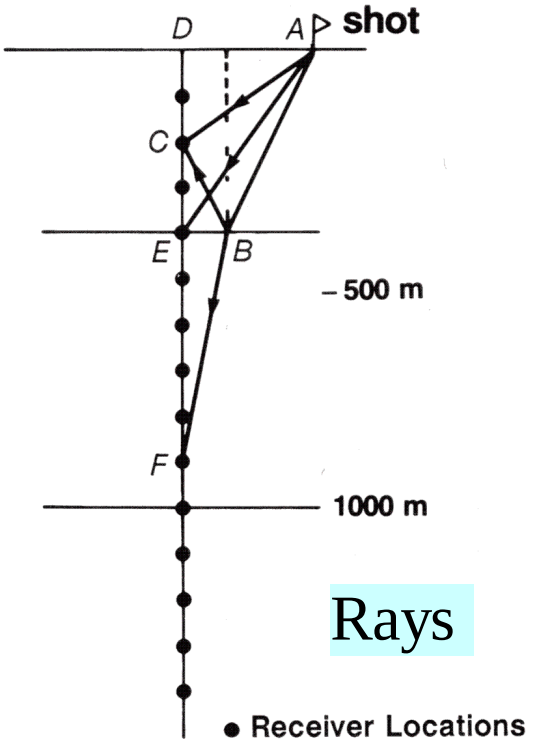
Table 13.1 *Objectives of VSP surveys*

Objective	How achieved
Reflector identification Surface-to-borehole correlation Increased resolution at depth	Upgoing wave studies on zero-offset VSP
Time–depth conversion Enhanced velocity analysis Log calibration	First-break studies on zero-offset VSP
Multiple identification Deconvolution operator	Downgoing wave studies on zero-offset VSP
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 Polarization studies Fracture orientation	Research study on offset VSP, three-component phone
Attenuation analysis	Research study on zero-offset VSP
Secondary recovery Tomographic studies Permeability studies	Research study on offset VSP Multiple wells, multiple offsets Tube-wave analysis research study

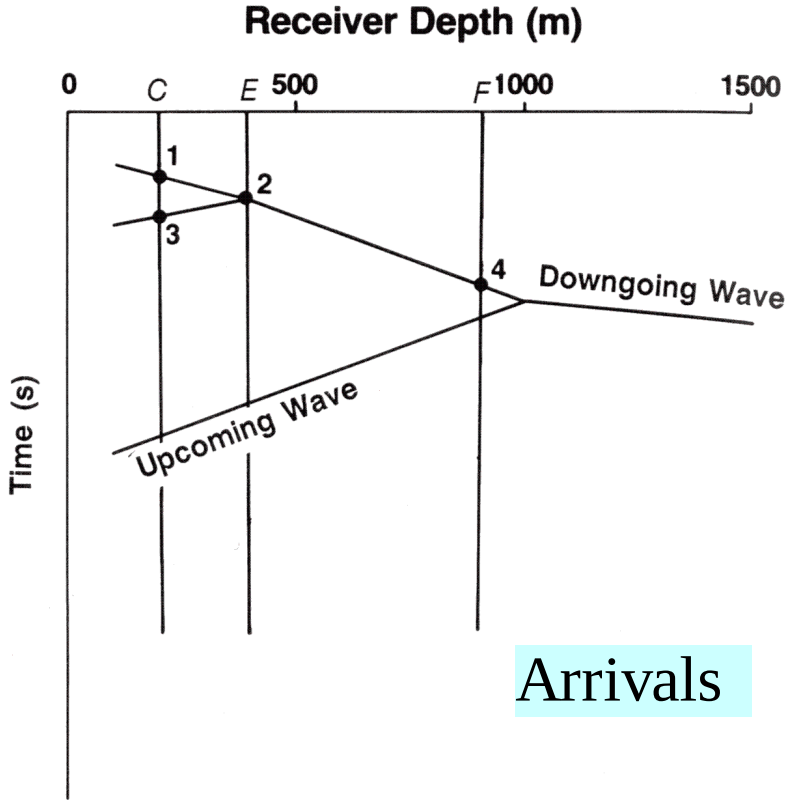
After Gilpatrick and Fouquet, 1989.

VSP geometry

- *Downgoing* and *upcoming* waves can be directly observed and isolated.
- To transform reflection times into *vertical-incidence times*, 2 steps are performed:
  - "VSP static correction" - mapping of time ABC into ABC + CD;
  - For offset VSP, NMO correction maps ABCD times into DE.

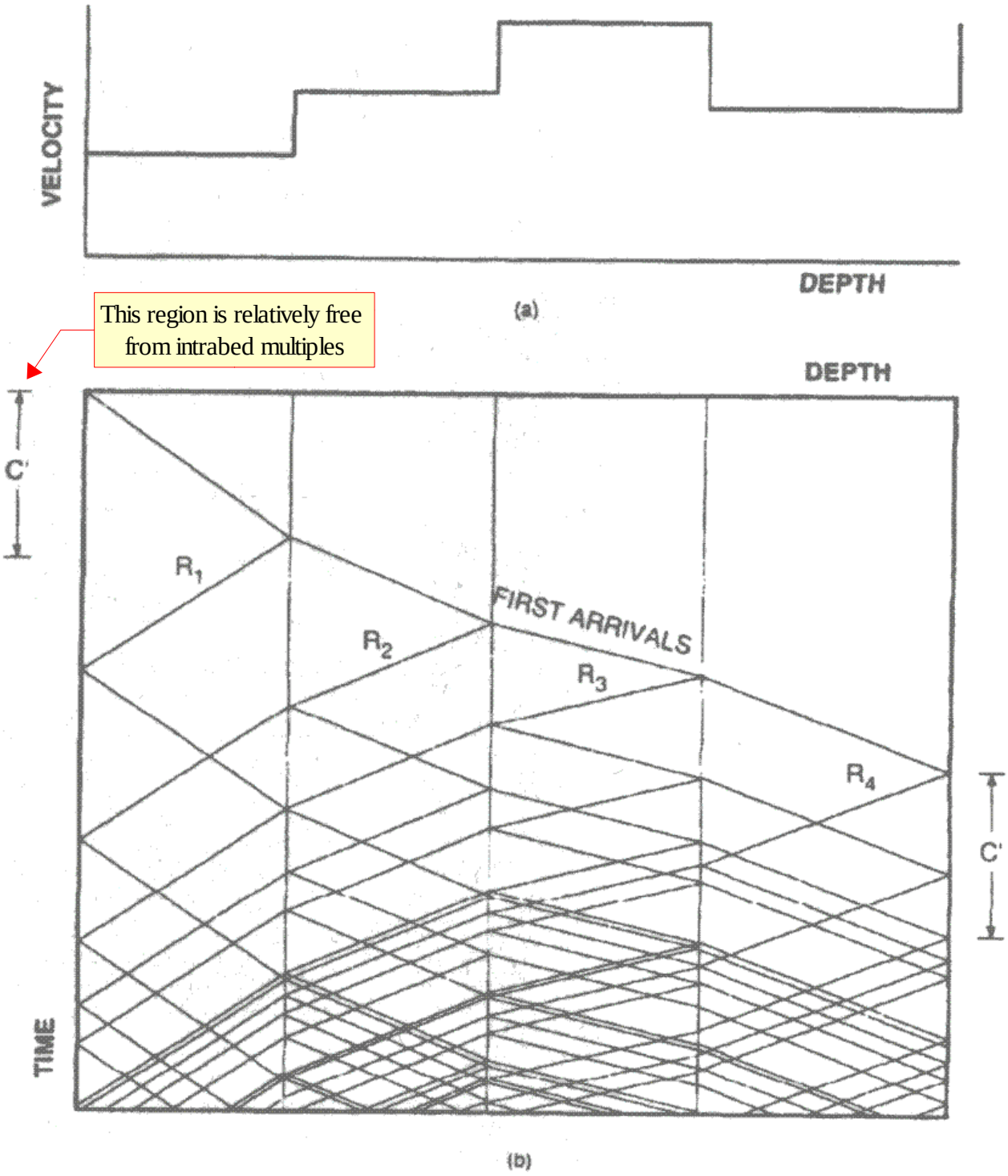


Rays



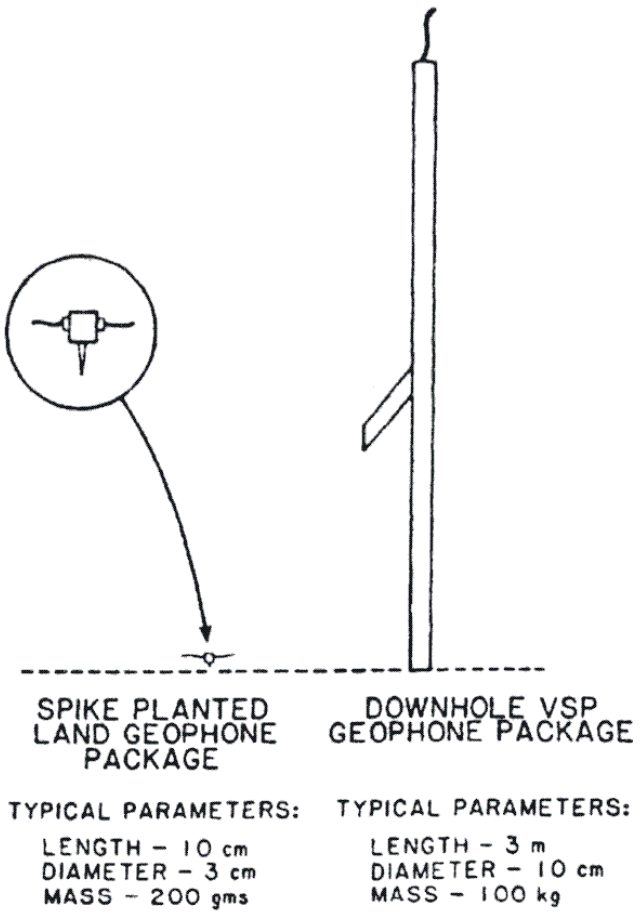
Arrivals

Multiples in a VSP section



Surface vs. VSP geophone

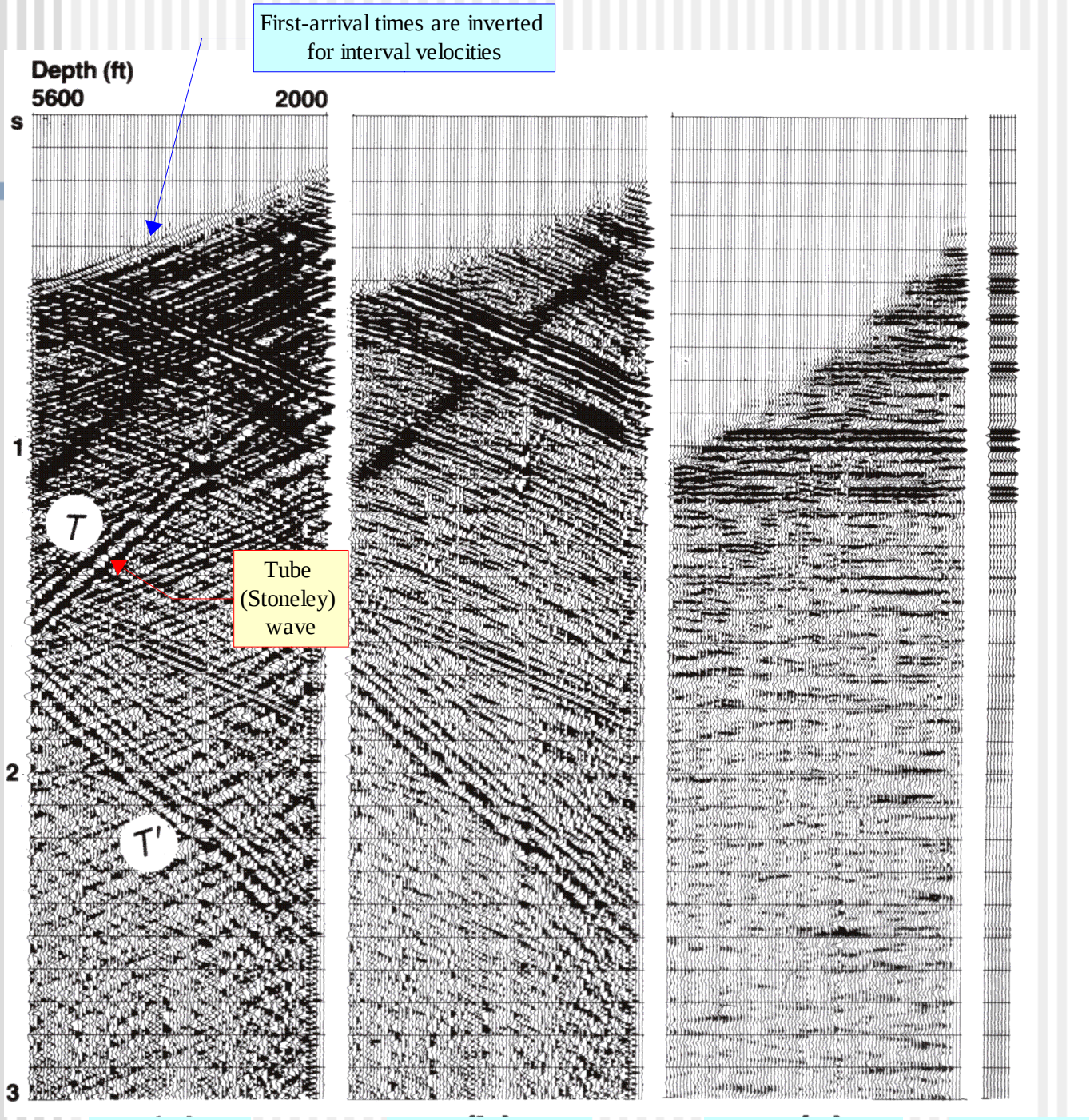
- VSP sonde should:
  - be 3-component; contain several levels;
  - include a retractable anchoring device;
  - contain orientation gear (a gyro);
  - withstand temperatures, pressures and fluids.



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



Raw data

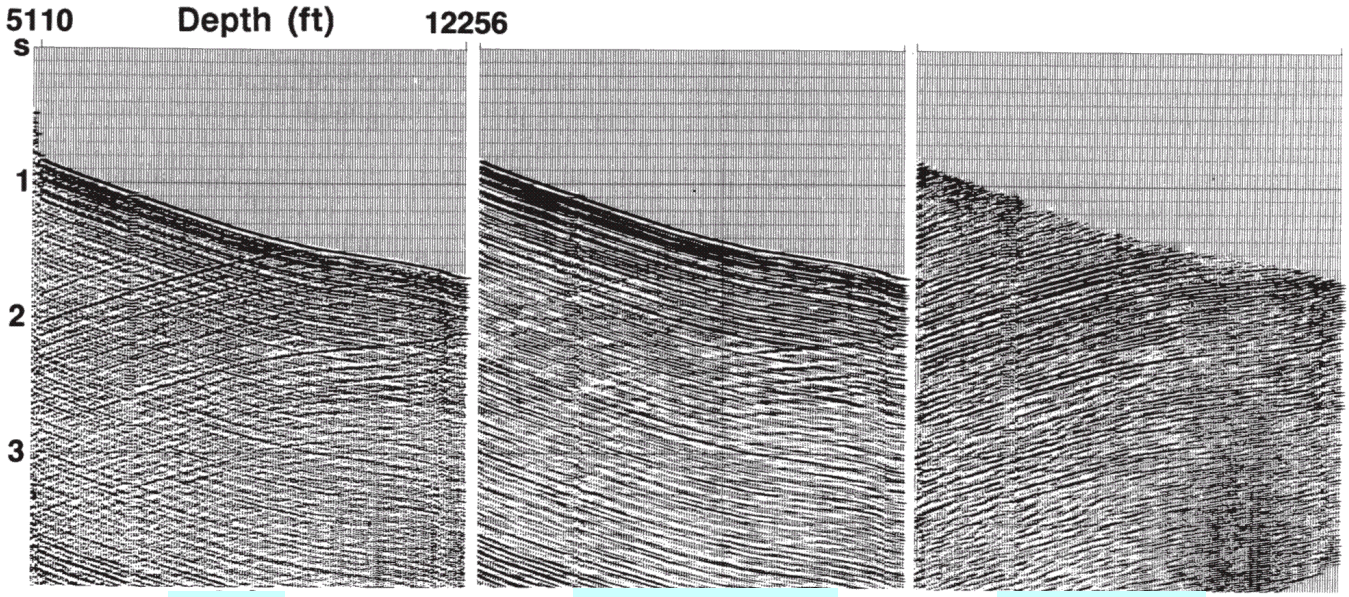
Upcoming waves extracted by *f-k* filtering

First-arrival time applied as statics

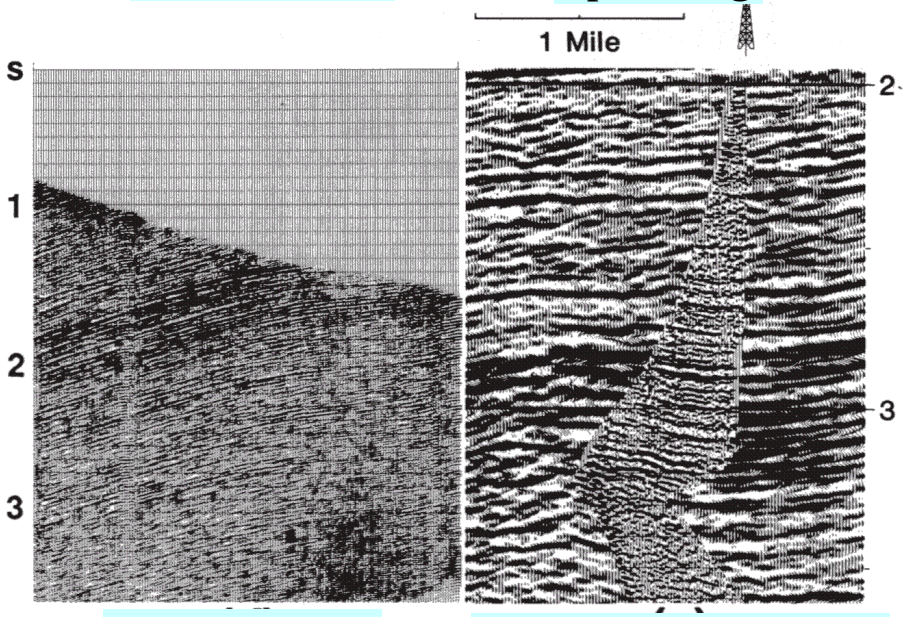
Corridor stack

VSP data processing

another example



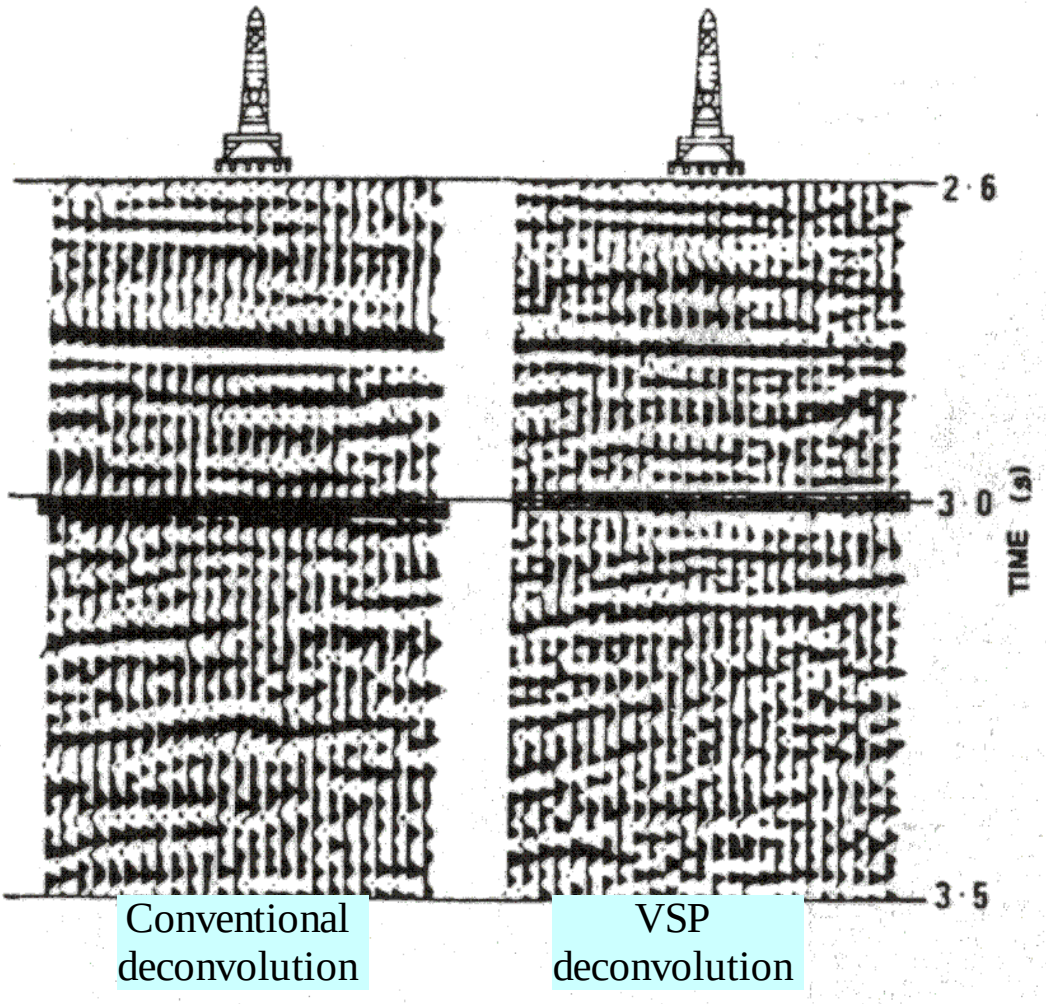
Raw | Downgoing | Upcoming



Deconvolved | Combined with CMP

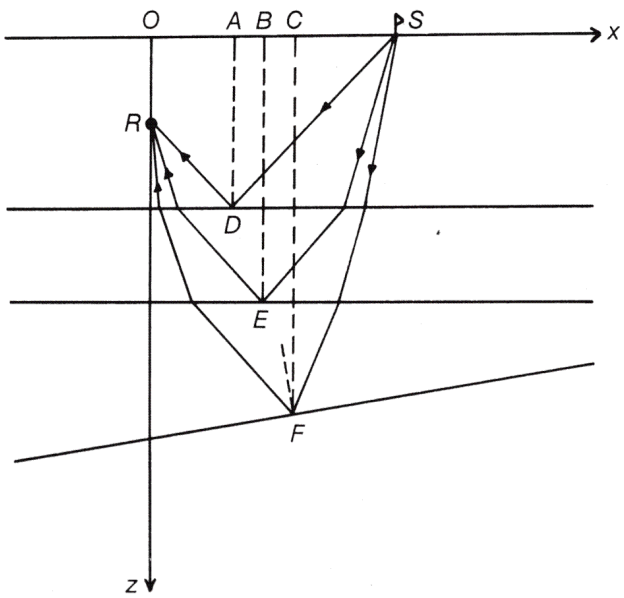
VSP deconvolution

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

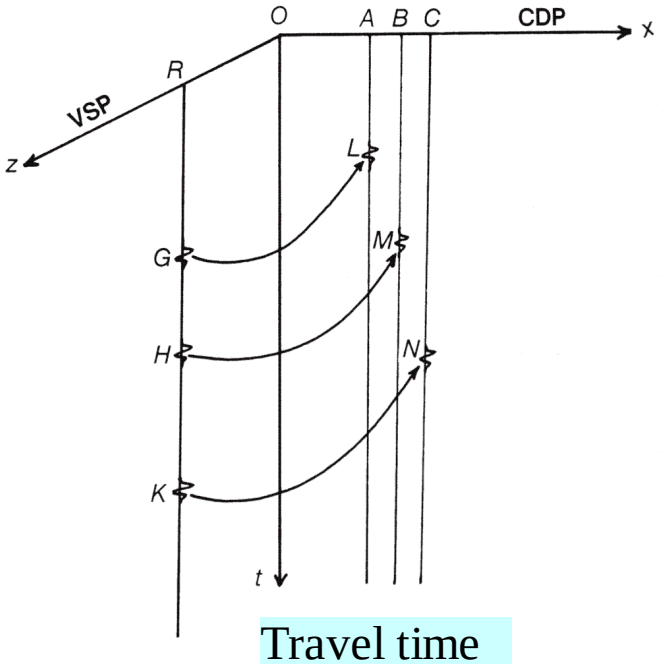


VSP migration
(dipping reflectors)

- Travel times are mapped into depth via ray tracing;
  - this is “pre-stack” migration.
- VSP apertures are limited, so need to know the dominant dip or use other constraints



Rays



Travel time to depth mapping