SEISMOLOGY

- Utilizes seismic (two types of sound) waves to make statements about the Earth's structure.
- By far the highest-resolution geophysical technique.
- As a *Geophysics* discipline, consists of:
  - Measurements ('data acquisition');
    - Emphasis on efficient acquisition techniques, vast volumes of data;
  - Data processing and analysis;
    - Very important and computer-based;
  - Interpretation in terms of models and geological concepts:
    - Forward (direct) modelling – predict seismic observations in a known subsurface structure;
    - Inverse modelling - Given the observed wavefield (travel times), determine the structure *and its uncertainty*.
      - Usually integrated with surface and borehole observations.
- Reading:
  - Telford *et al*., Chapter 1.
  - Shearer, Chapter 1

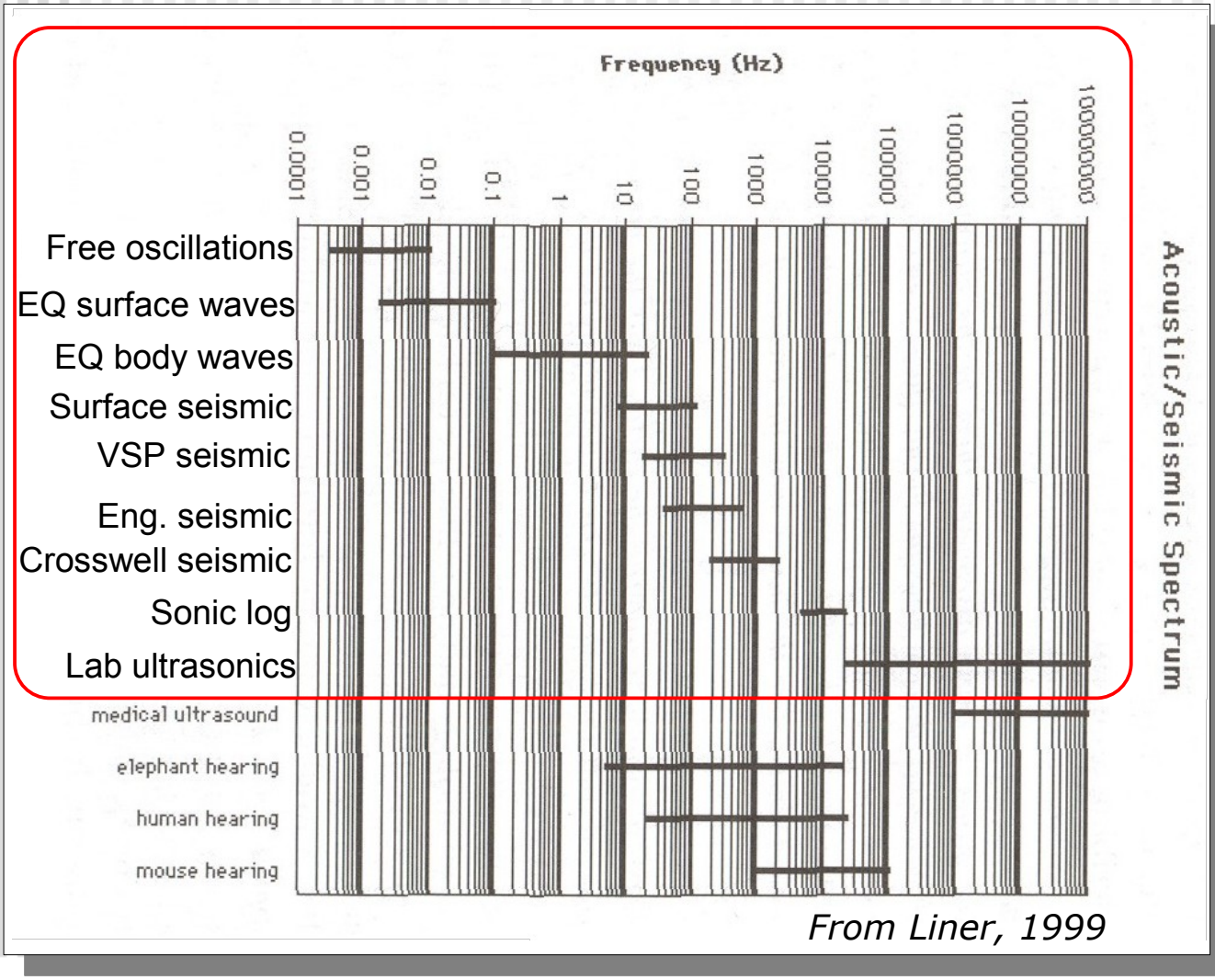
Seismic Methods

Their **Resolution**; 'Passive' and 'Active'

Method	*Property*	*Resolution*	*Value Measured*
Surface refraction	Velocities, velocity gradients	20 m-100 km	Travel times
Surface reflection	Impedance contrasts	0.5 – 20 m	Travel times, amplitudes, reflection patterns
Vertical seismic profiling	Velocities, reflectivity	0.2 – 5 m	Travel times, waveforms
Borehole acoustic logs	Velocities near the borehole, at ~10 – 50 kHz	0.1 m	Pulse time delays
Borehole cross-well	Velocity contrasts at ~10 - 50 kHz	~5 m	Travel-time delays
Laboratory ultrasonic	Velocities at ~100 kHz, anisotropy	1 – 5 cm	Travel times in samples
Surface waves	Velocity structure (primarily of S-waves)	10 m – 100 km	Phase spectra of waves from artificial and natural seismic sources; Dispersion curves
Monitoring	Location of creep within reservoirs and mines, natural earthquakes, weapons tests	100 m – 30 km	Travel times
Teleseismic	Location of earthquakes, velocity structures, reflecting and converting boundaries	30 – 100 km	Waveforms of body and surface waves (~1-1000 sec periods)
Normal modes	Whole-Earth oscillations	1000 km	Earth movements at > 1000 sec periods

Acoustic/Seismic Spectrum

- Key to *signal penetration* and *resolution*:
  - Resolution (the amount of resolvable detail) is typically *proportional* to frequency;
  - Signal penetration quickly *decreases* with increasing frequency.

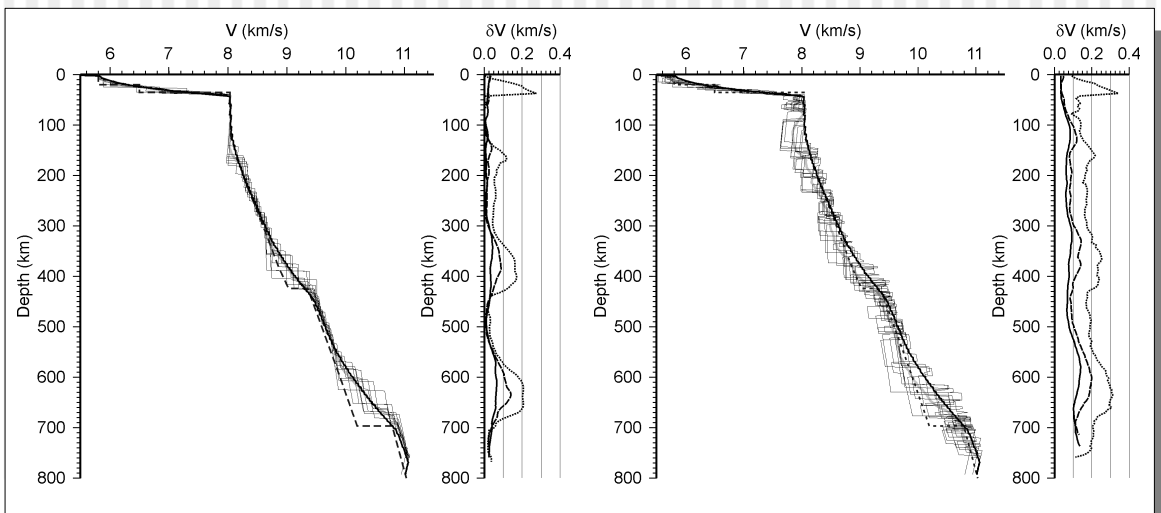


From Liner, 1999

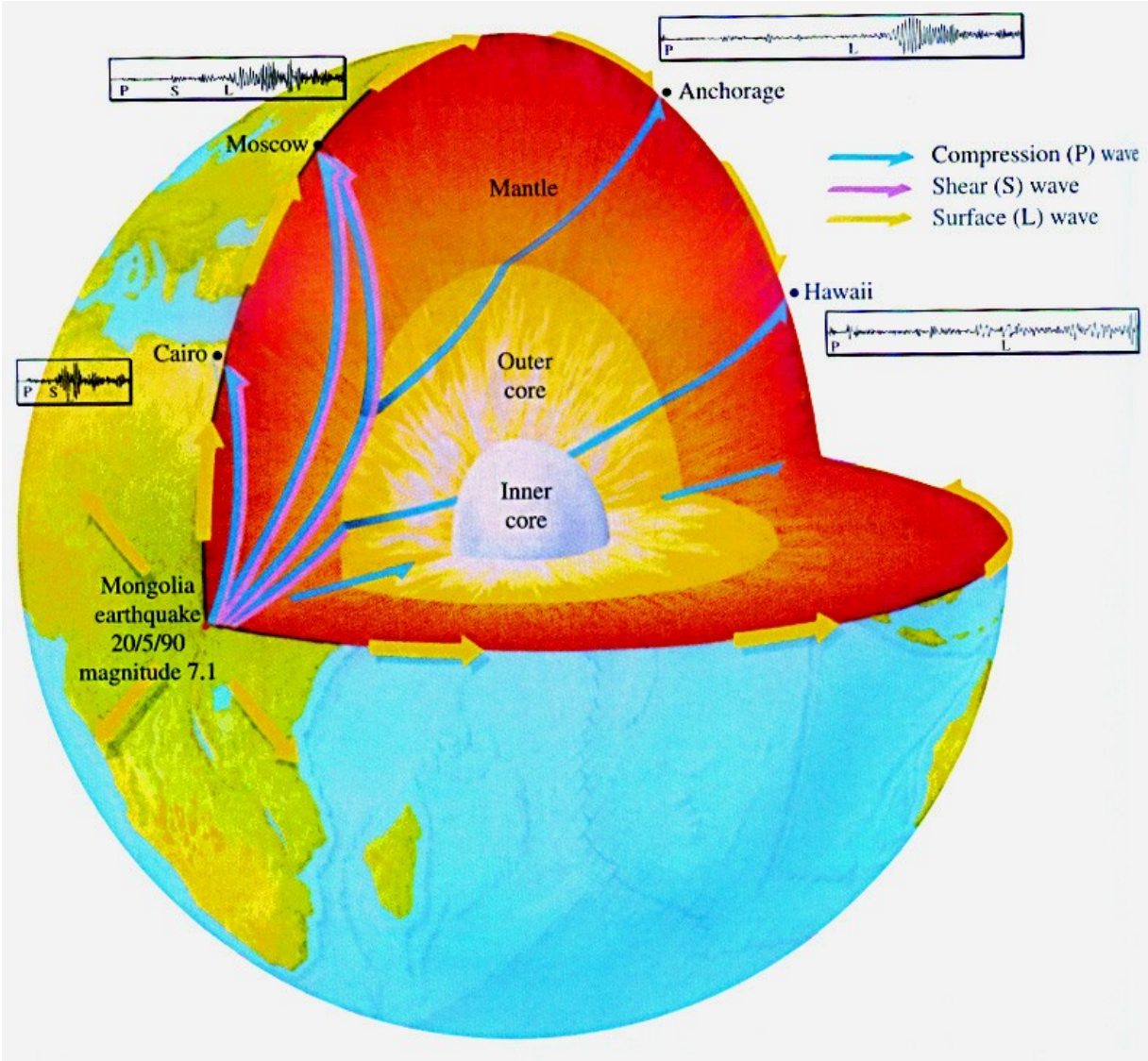
Earth is complex

and so are the observations, but models are always simplified

- Observations are limited to the surface or a few boreholes.
- Different rocks often have similar seismic properties:
  - Seismic waves are sensitive to combinations of V_P, V_S, and density;
  - Spatially-averaged and sample-derived properties are different;
  - Seismic properties are often *frequency-dependent*.
- Therefore, ambiguities in interpretations are common.
  - Solution – always estimate the errors and apply multiple methods to remove

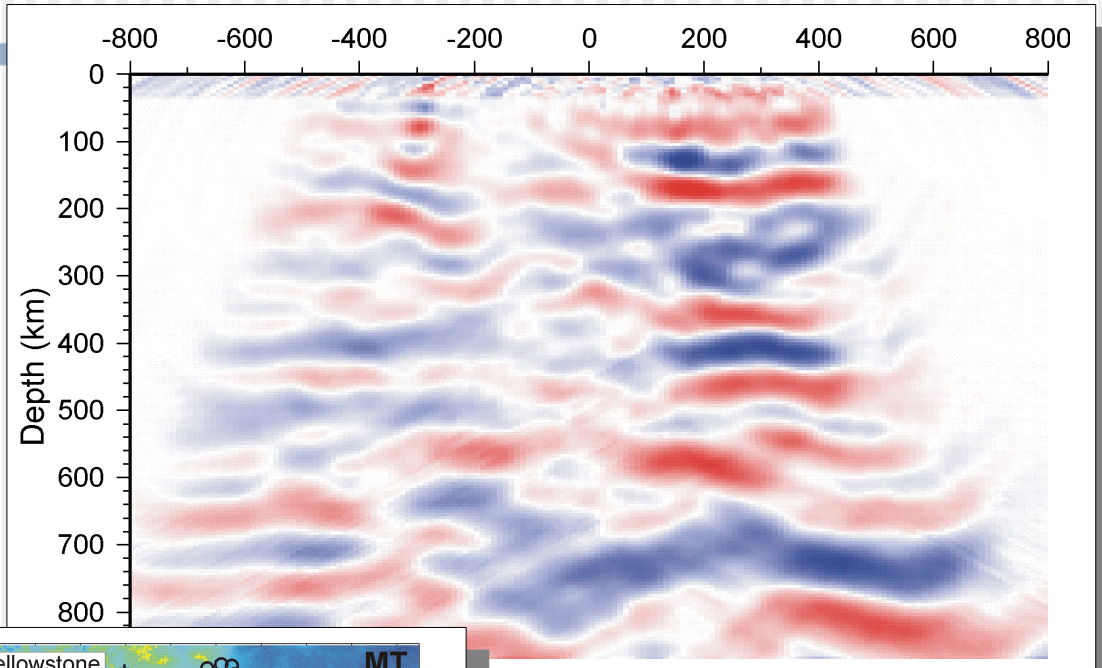


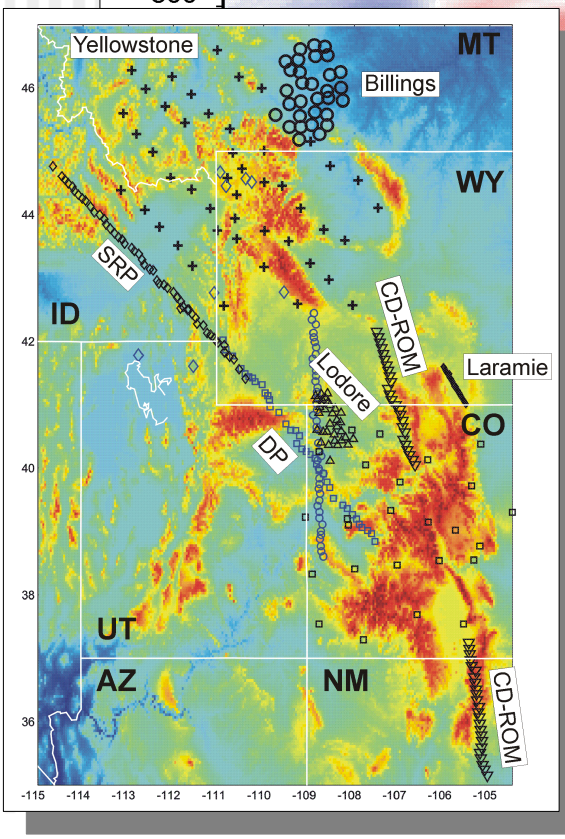
Earthquake seismology



Teleseismic

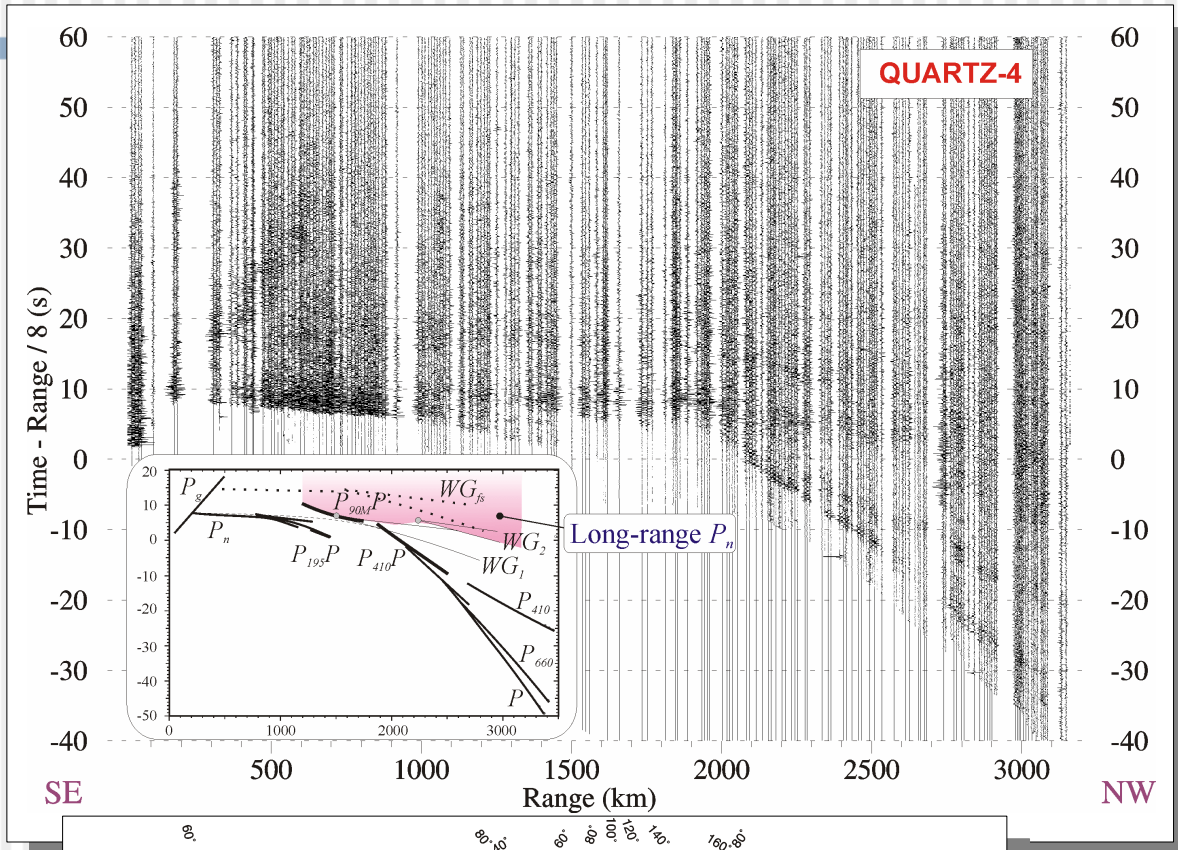
(Using signals from earthquakes beyond ~2500 km)

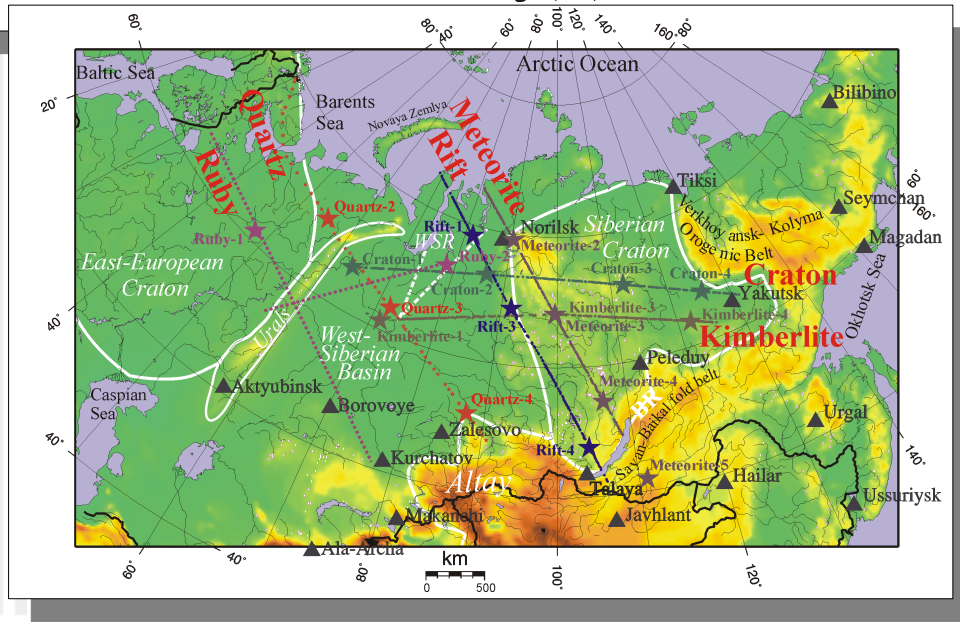




- Mantle velocity variations;
- *P-S* 'converting' boundaries within the mantle.

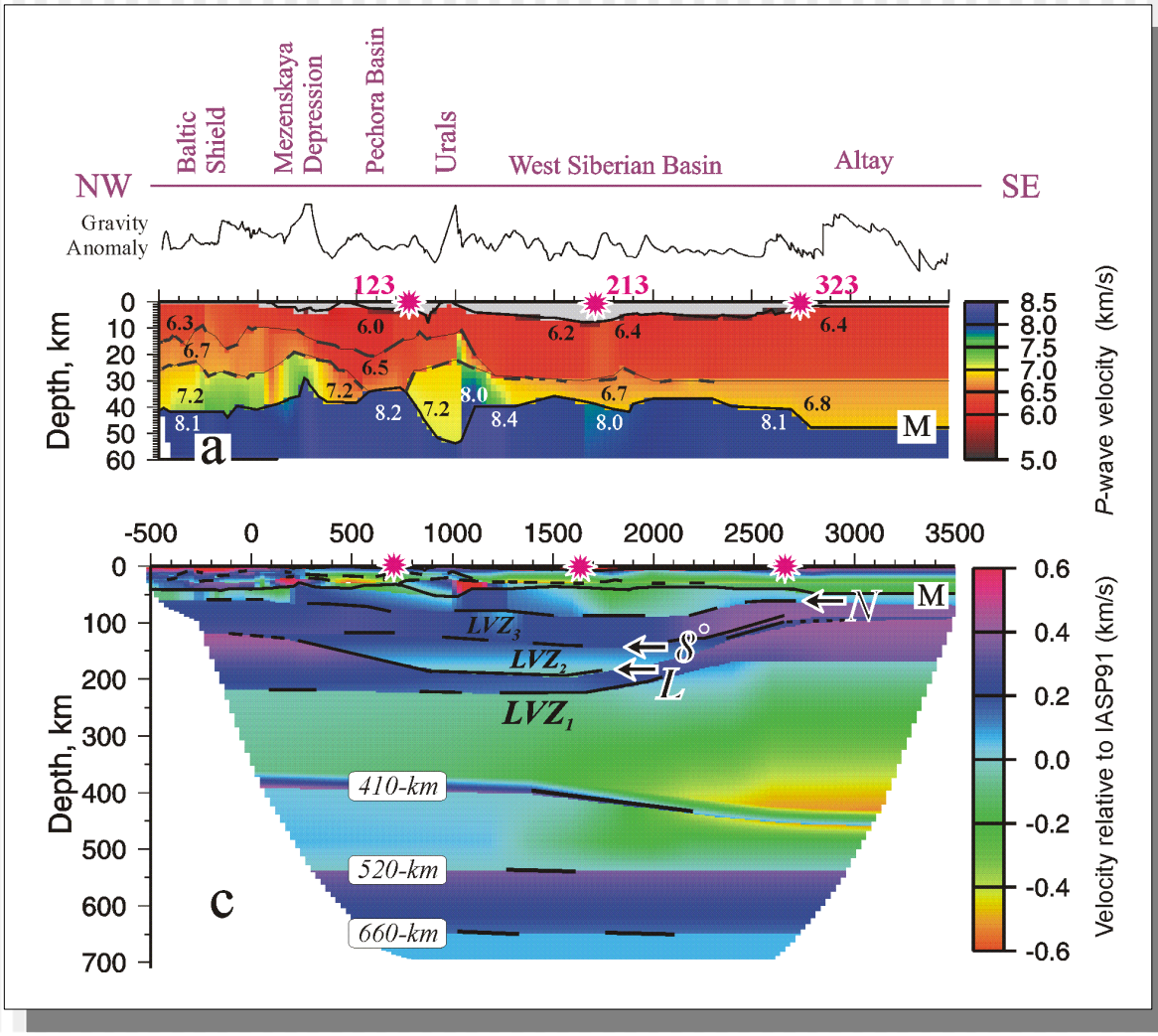
Nuclear Explosions



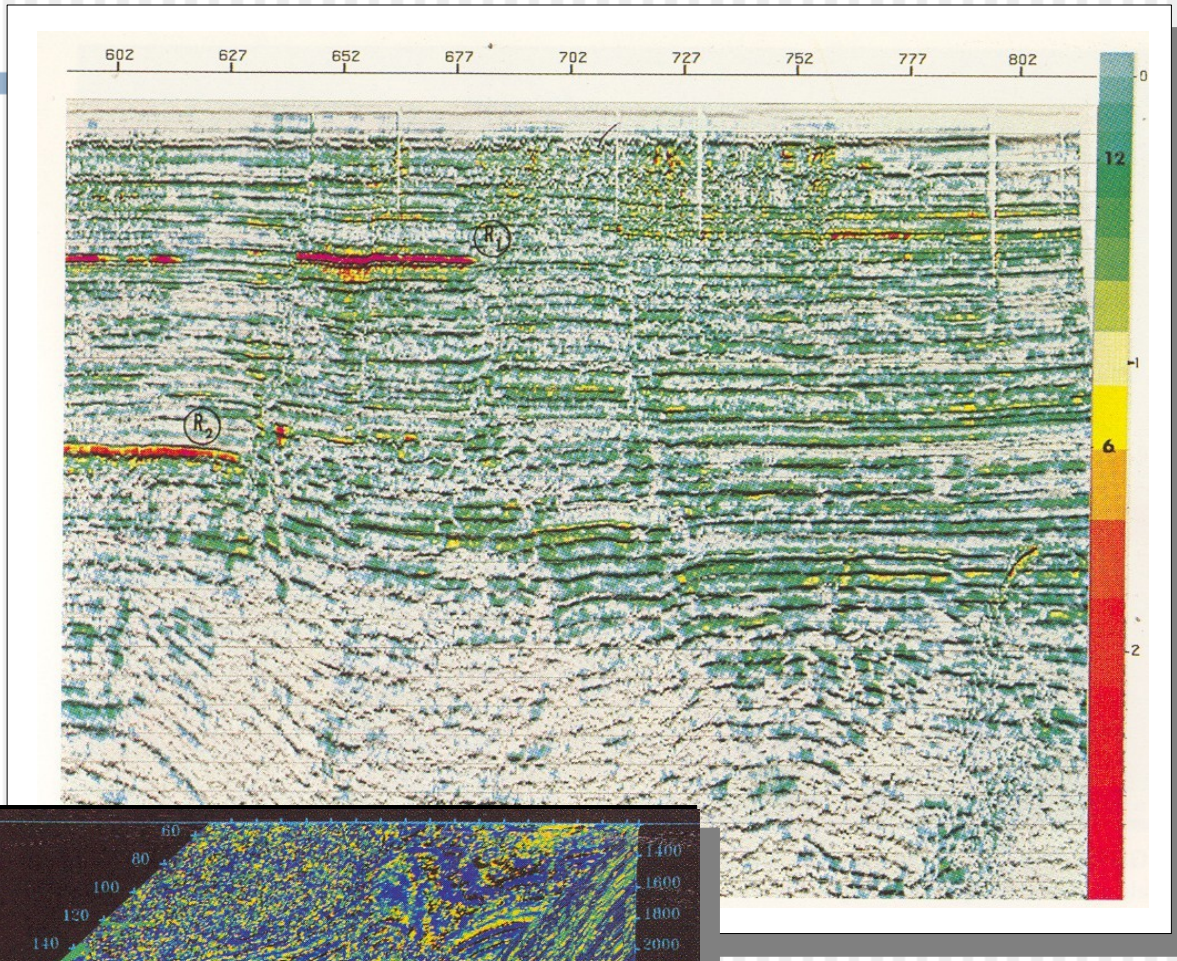


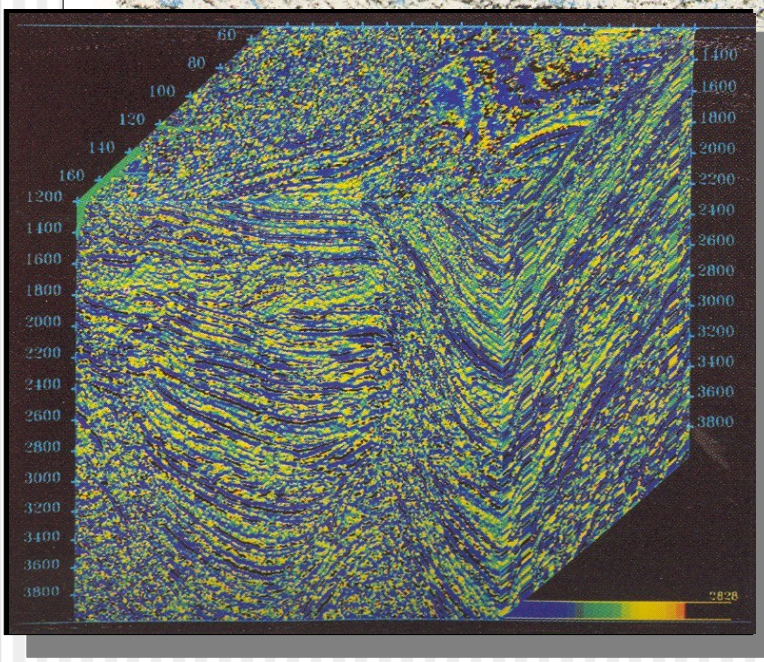
Deep structure

- Velocity heterogeneity;
- Reflecting boundaries;
- Attenuating zones (partial melts?) within the mantle.
- Scattering zones (?).



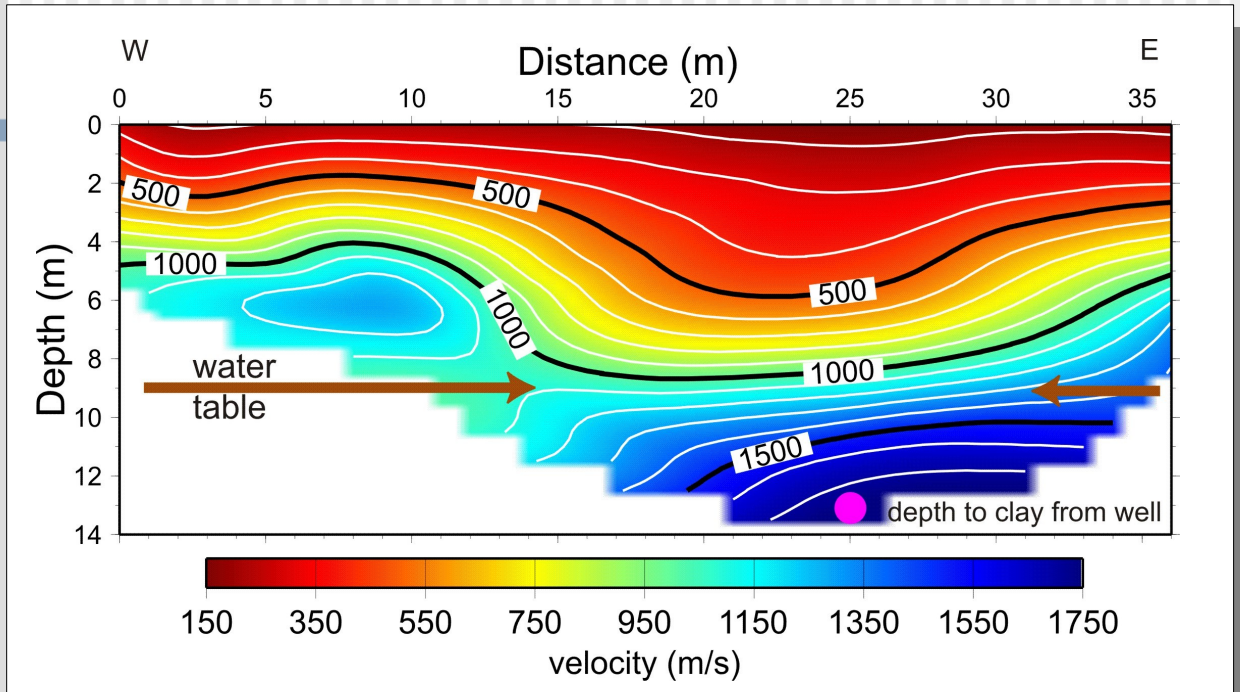
Oil/Gas exploration seismology

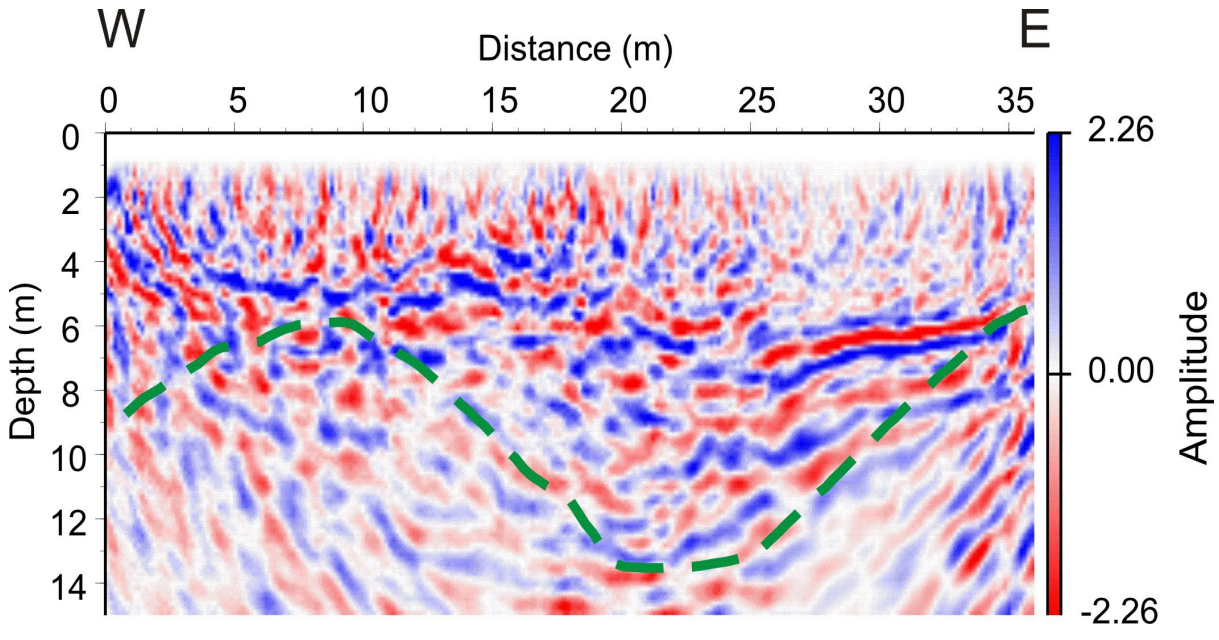




- Large volumes;
- Great amount of detail;
- High accuracy;
- Multi-step and intricate processing

Shallow seismology





Key texts

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ge-o-phys-i-cist, *n*.

A geophysicist is a person who passes as an exacting expert on the basis of being able to turn out, with prolific fortitude, infinite strings of incomprehensible formulae calculated with micrometric precision from vague assumptions, which are based on debatable figures taken from inconclusive experiments, carried out with instruments of problematic accuracy by persons of doubtful reliability and questionable morality for the avowed purpose of annoying and confounding a hopeless chimerical group of fanatics known as geologists who are themselves the lunatic fringe of the scientific community.