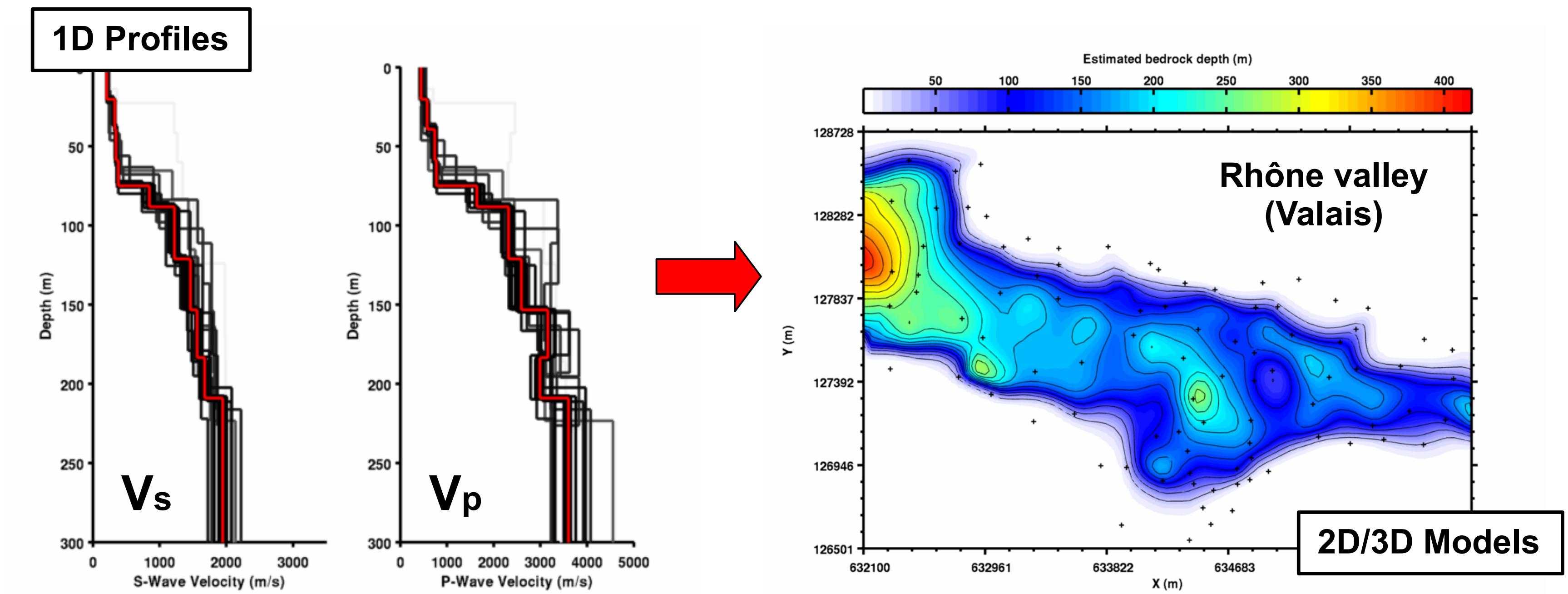
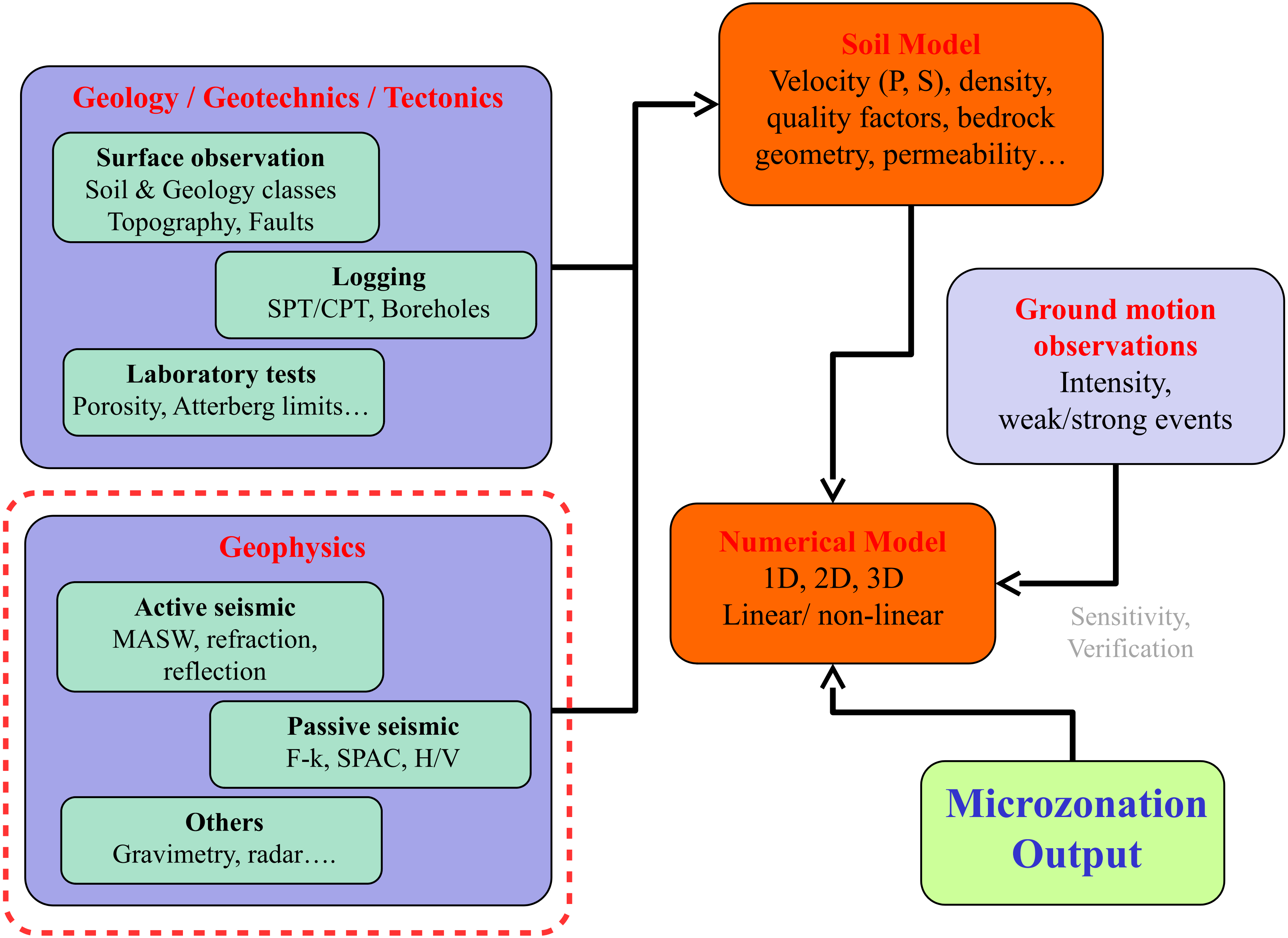
Site Characterization Techniques

Ground Parameter Overview

- The most relevant parameters to characterize the soil behavior are the **seismic velocity of body waves** (Vp and Vs), the **density** (ρ) and the **attenuation factors** (Qp and Qs)
- The way these parameters are geometrically distributed controls the modification of ground-motion during an earthquake
- **Shear wave velocity**, in particular, is the most important property in engineering applications
- A sufficient knowledge of these parameters is essential for any **interpretation of recorded earthquake ground motion**




Geology / Geotechnics / Tectonics
Surface observation
Soil & Geology classes
Topography, Faults
Logging
SPT/CPT, Boreholes
Laboratory tests
Porosity, Atterberg limits…
Geophysics
Active seismic
MASW, refraction, reflection
Passive seismic
F-k, SPAC, H/V
Others
Gravimetry, radar….
Soil Model
Velocity (P, S), density, quality factors, bedrock geometry, permeability…
Ground motion observations
Intensity, weak/strong events
Numerical Model
1D, 2D, 3D
Linear/ non-linear
Sensitivity, Verification
Microzonation Output

Indirect (geophysical) investigations

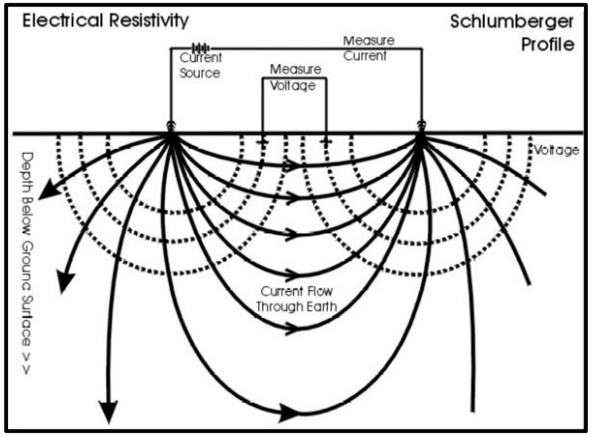
Indirect investigation techniques (or **geophysical methods**) use the properties of the **physical fields** (electric, magnetic, gravity, seismic) to infer information on the soil structure remotely (water table, bedrock depth)

Static-field methods:

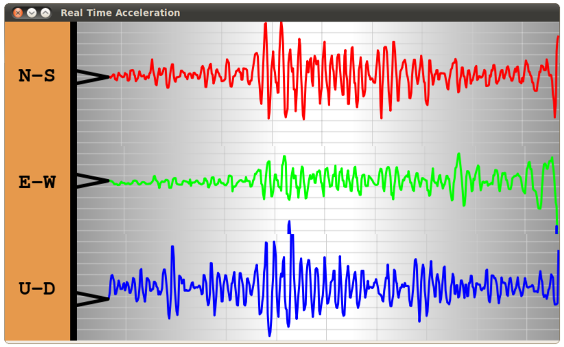
- Electrical methods (resistivity, self-potential)
- Magnetic method (magnetic susceptibility)
- Gravimetric method

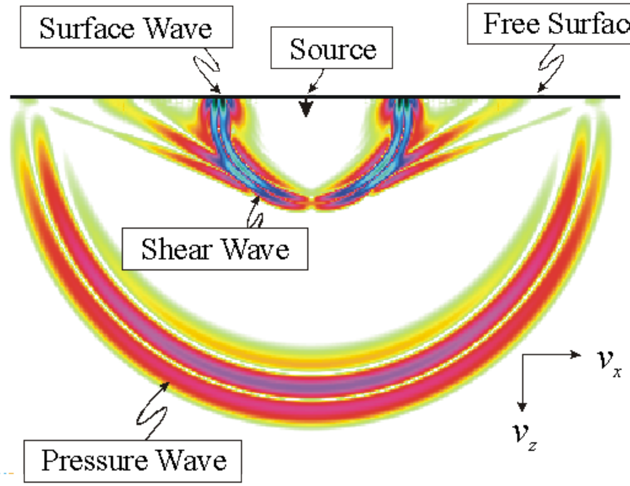
Wave-field methods:

- Electromagnetic methods (radar)
- Seismic methods (active and passive)



(http://www.earthdyn.com)





(http://acoustics.org/)

Active seismic methods

→ Make use of an **artificial sources** to generate a seismic signal
→ Two major categories: the **travel-time** and **surface wave methods**
→ The receivers can be located at the surface or in boreholes

Advantages:

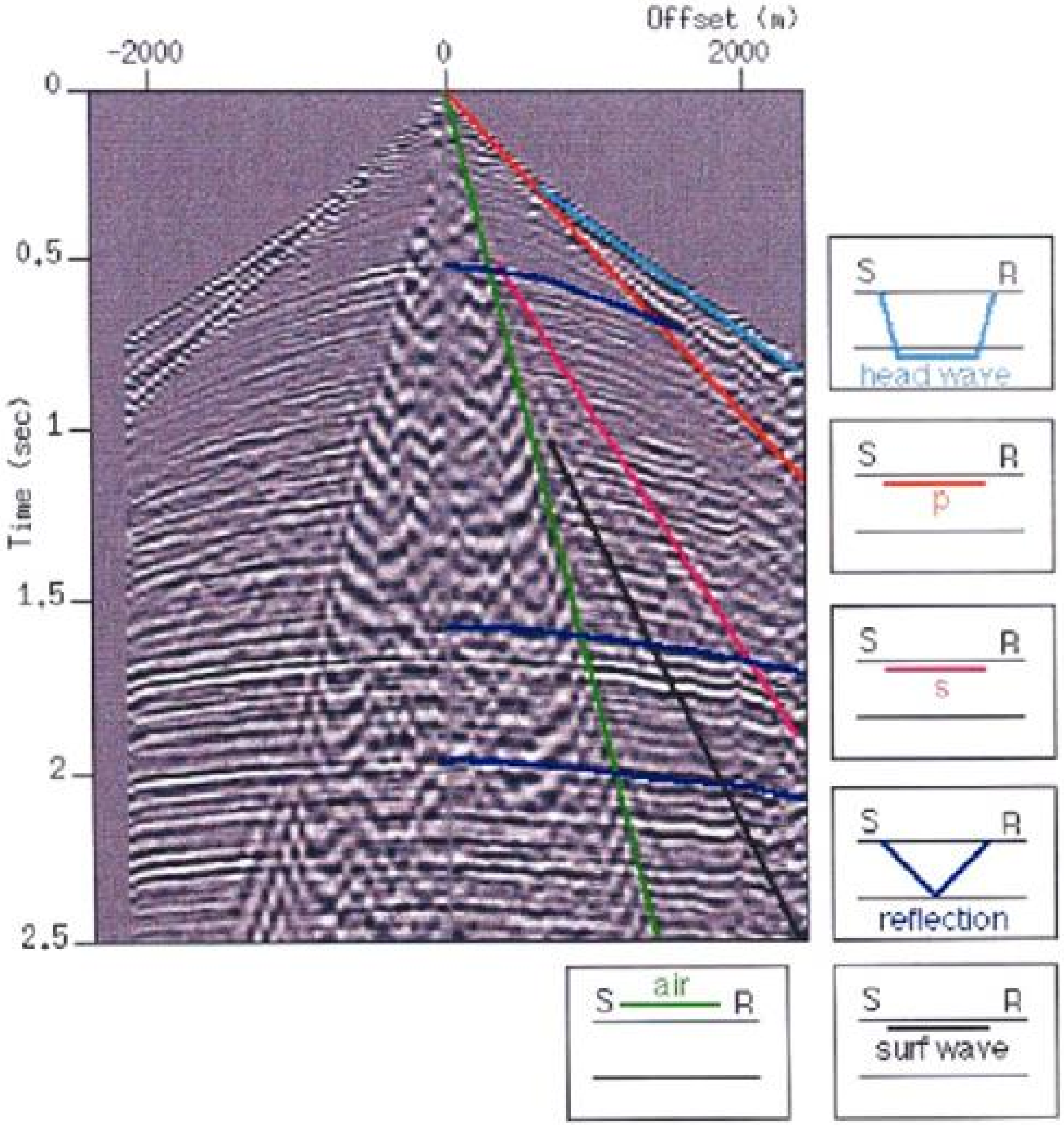
- Good signal quality in noisy environments
- Good resolution on the velocity profile

Disadvantages:

- Scarce penetration depth with conventional sources (e.g. hammer, minigun)
- Relatively high costs of implementation
- They can hardly be used in urban environment

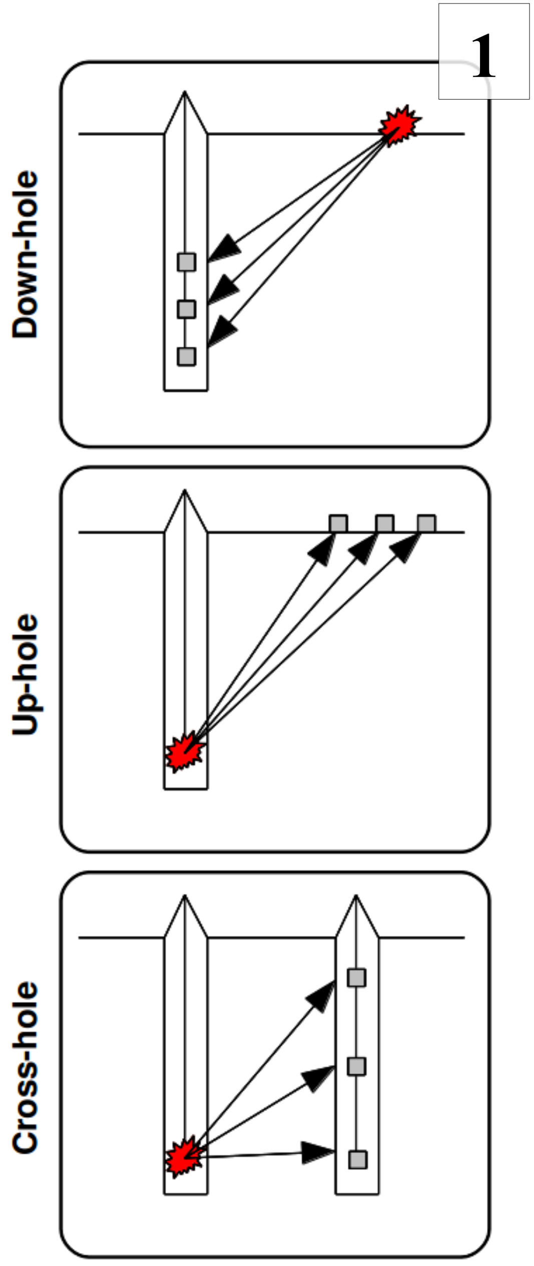
(http://www.earth.ox.ac.uk)

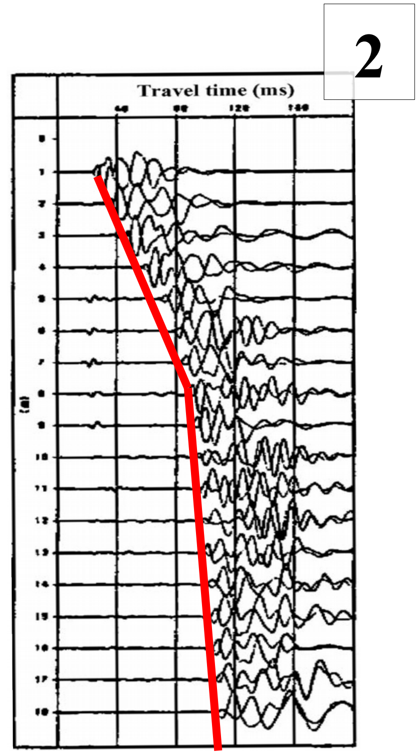
Wavefield complexity



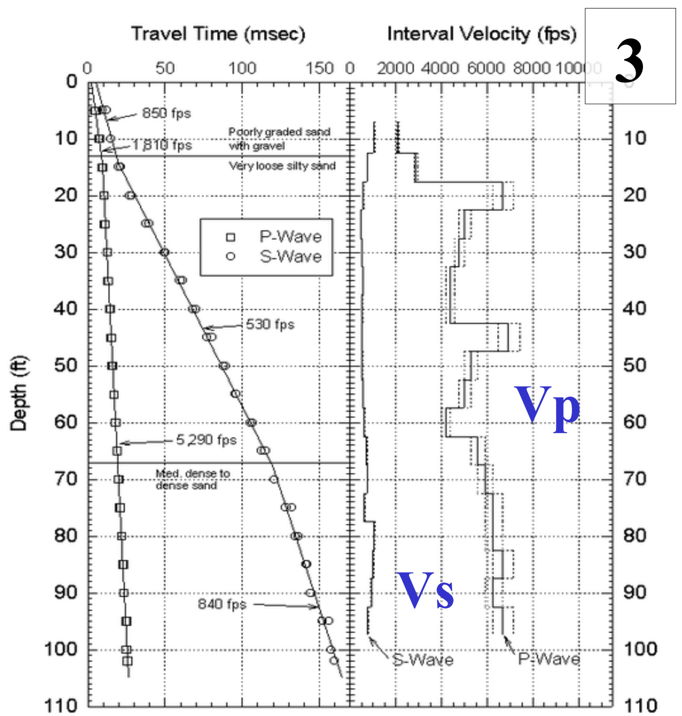
Borehole seismic

(Travel-time analysis)





Takahashi et al. IJRMMS. 2006



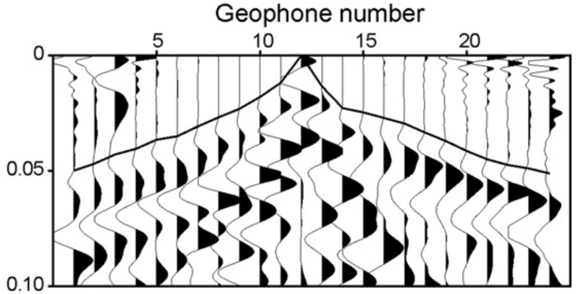
Typical results from downhole seismic survey

(http://www.earthdyn.com)

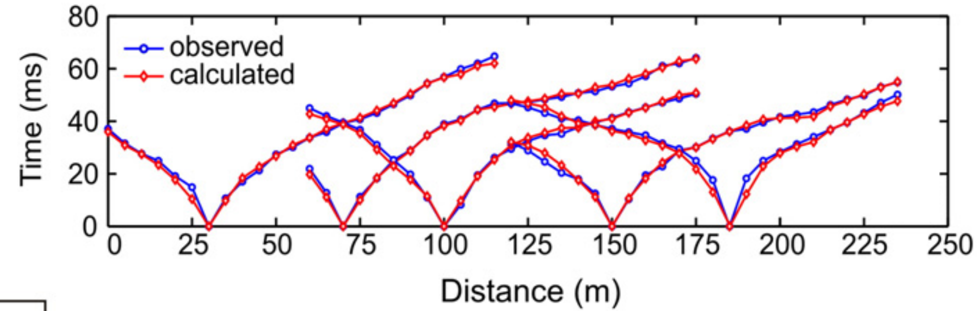
Seismic refraction analysis

(Travel-time tomography)

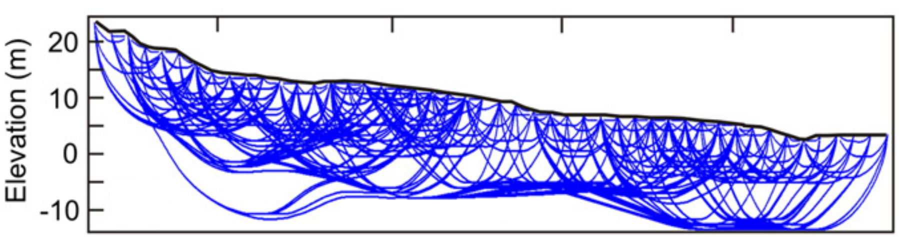
Acquisition



Travel time analysis

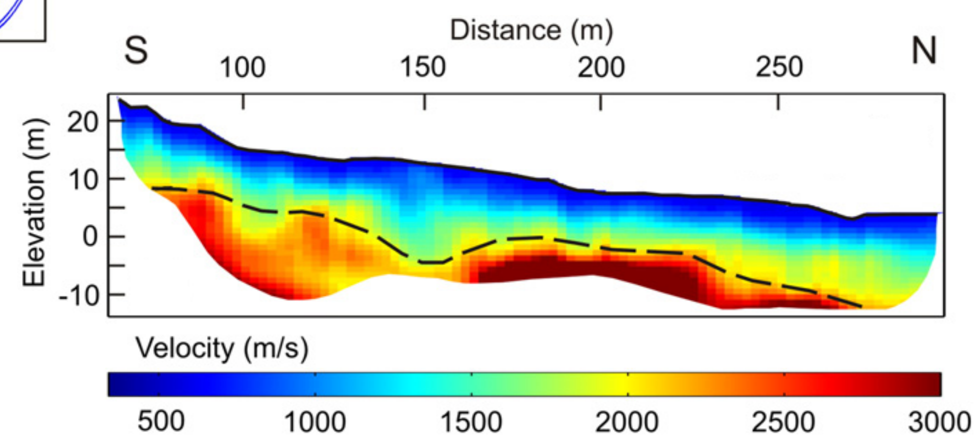


Ray-path modeling

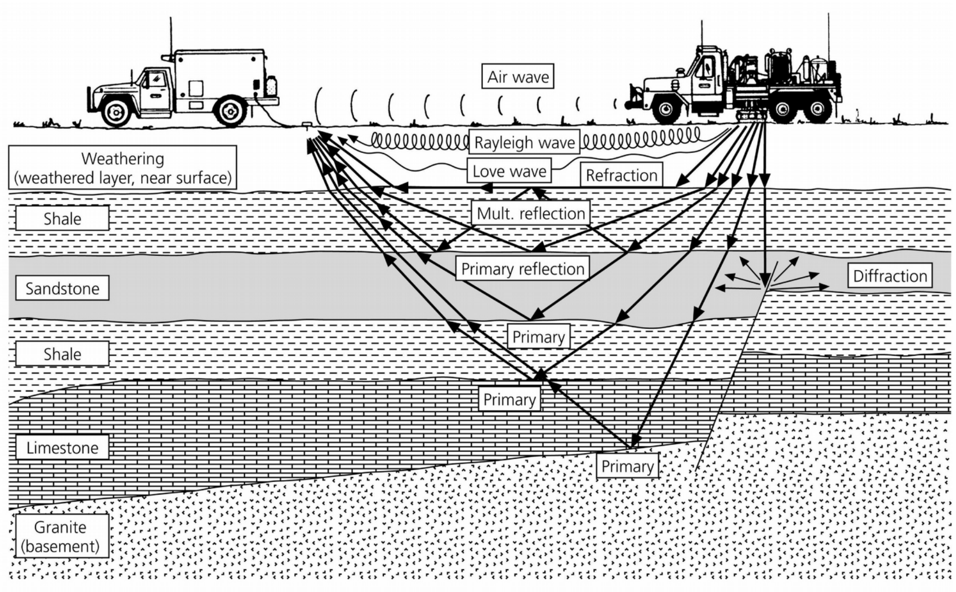


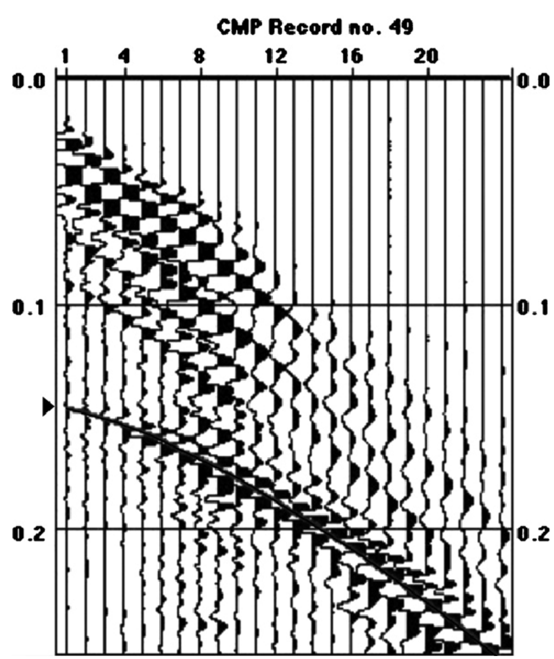
Göktürkler et al., JAG, 2008

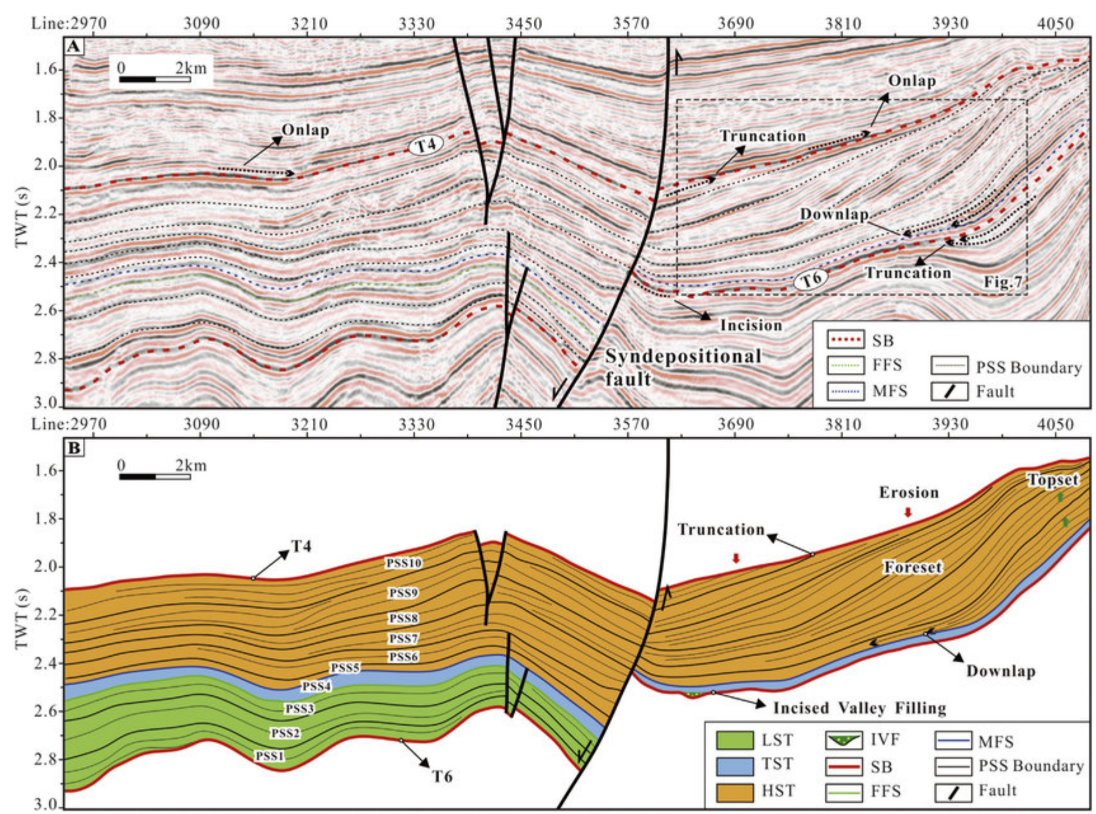
Velocity analysis



Seismic reflection analysis



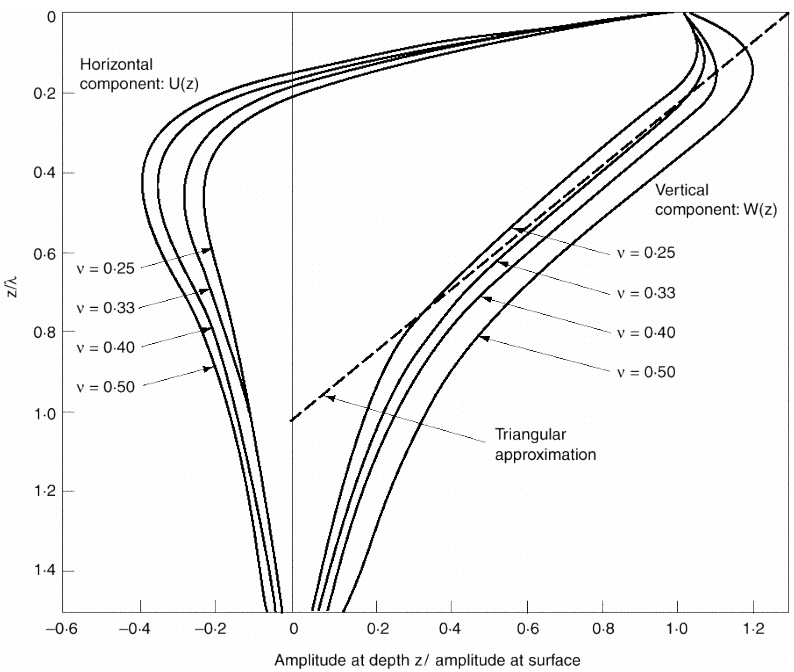


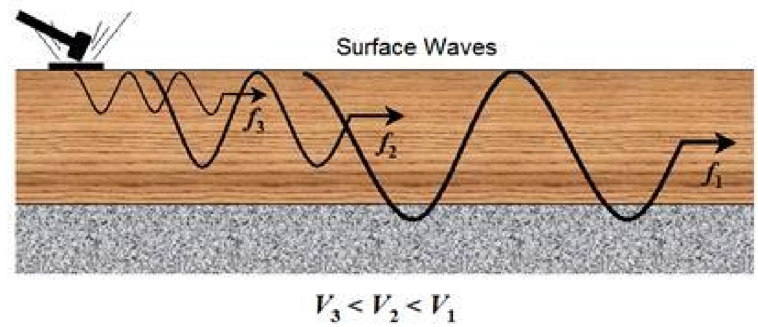


Surface waves

Displacement (**mode eigenfunction**) vanishes with depth

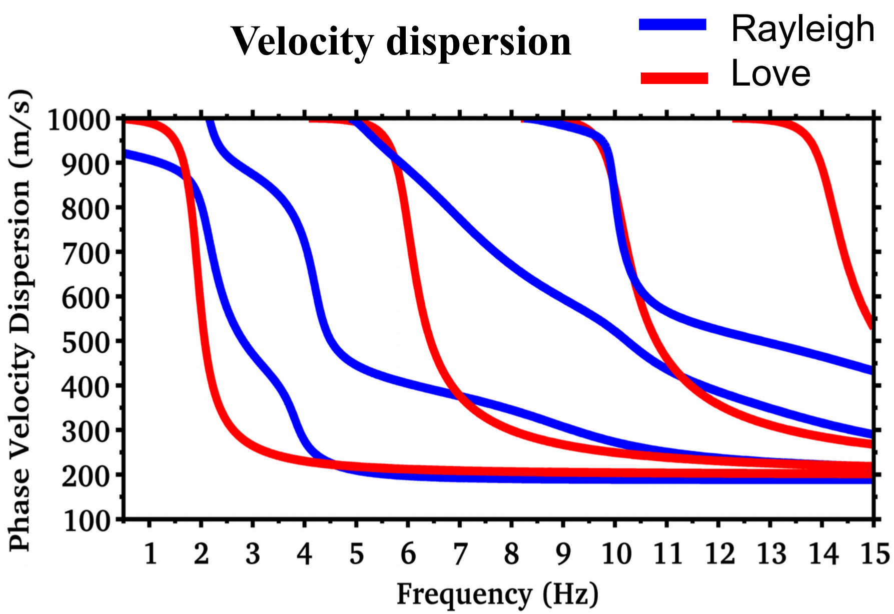
Eigenfunctions





- Velocity is frequency dependent (***velocity dispersion***)
- **Multiple modes** of propagation exist at the same time

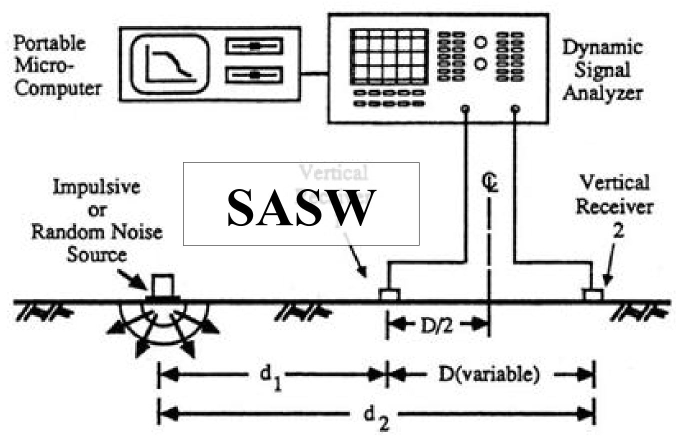
Velocity dispersion



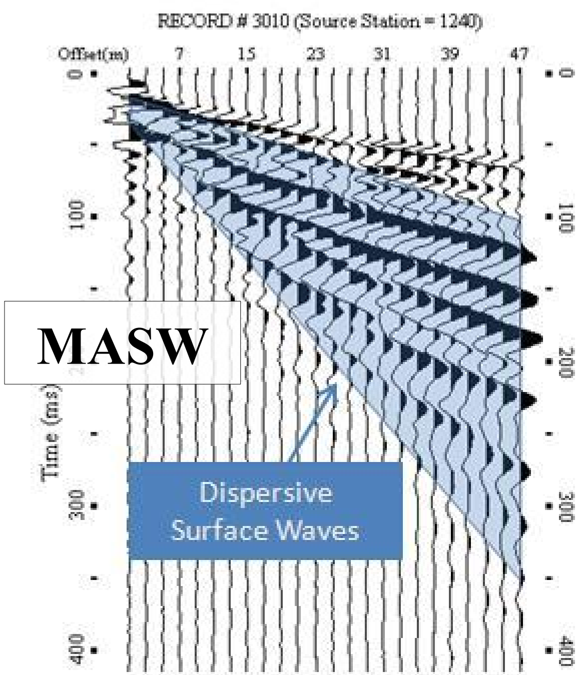
Active surface wave analysis

SASW → Spectral Analysis of Surface Waves (relative phase delay between pairs of receivers)

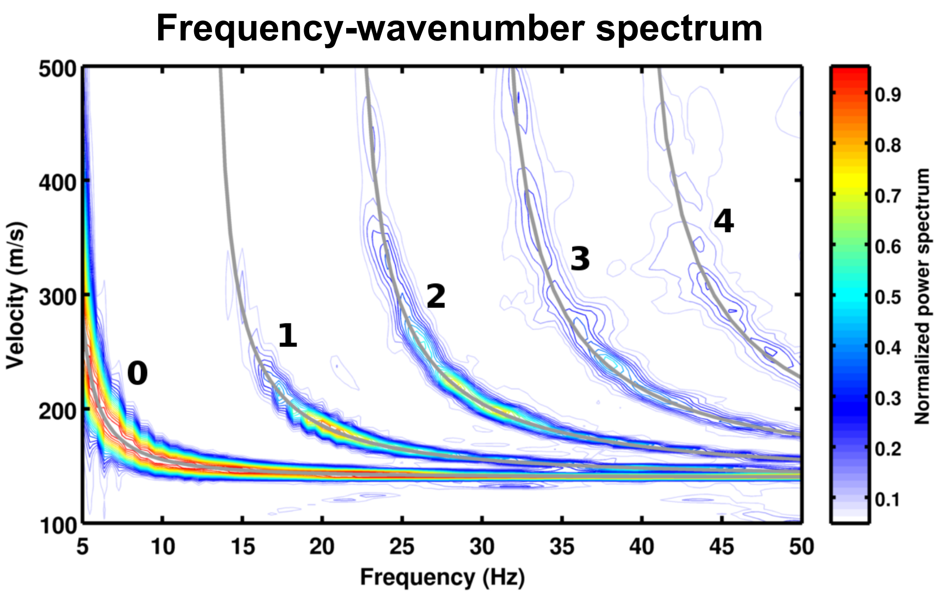
MASW → Multichannel Analysis of Surface Waves (frequency-wavenumber analysis)



From Rix et al. (1991)

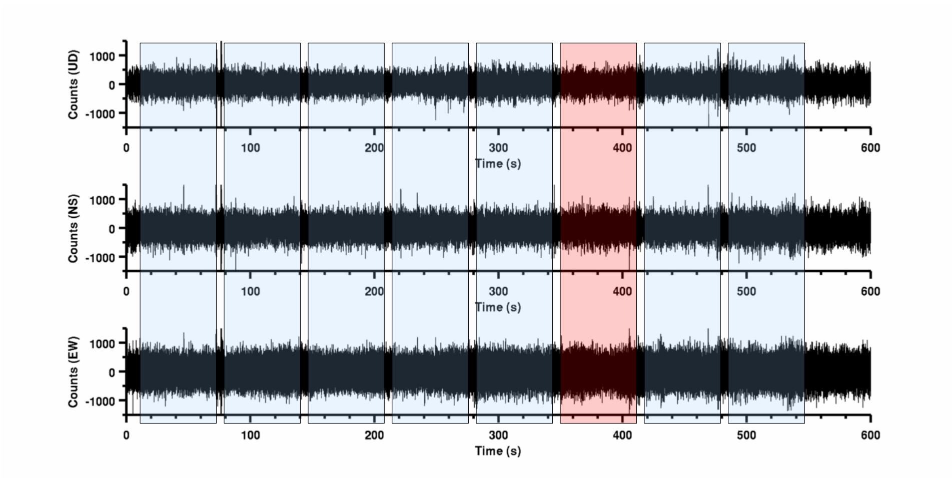


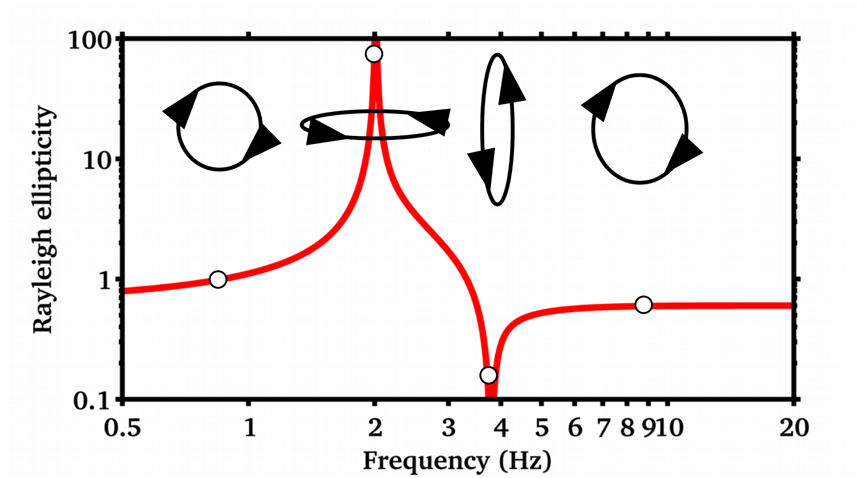
(http://www.parkseismic.com)

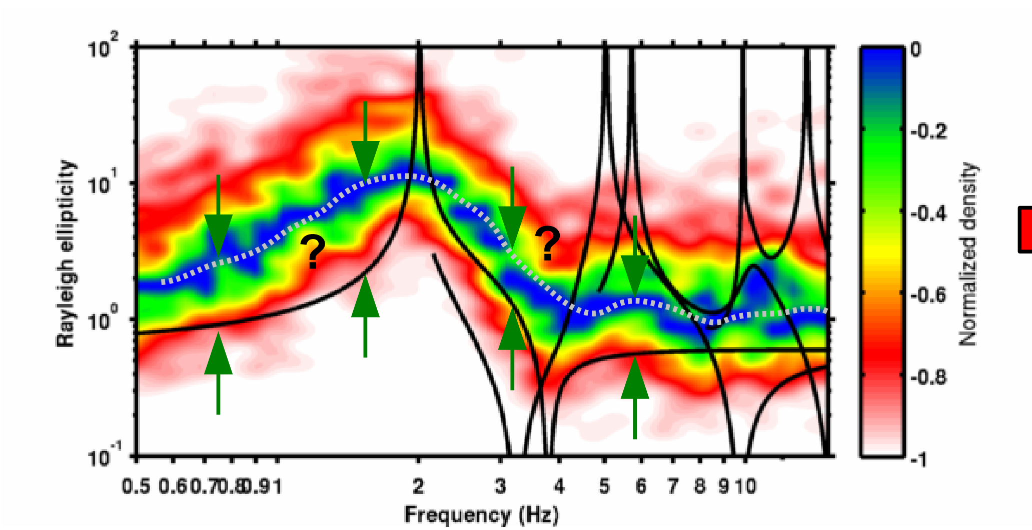


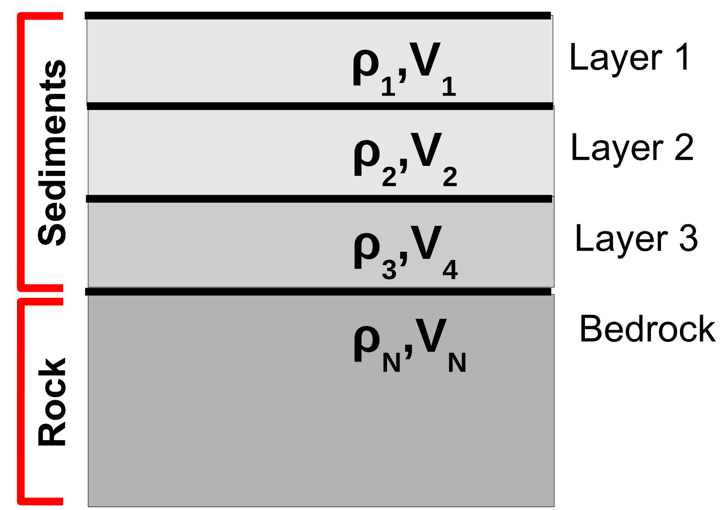
Ambient vibration seismology

(H/V Spectral Ratios)





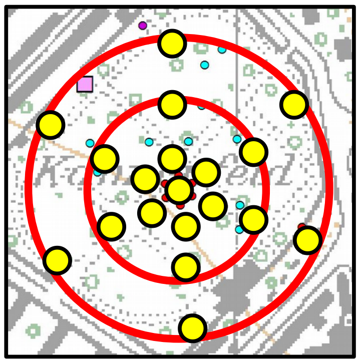




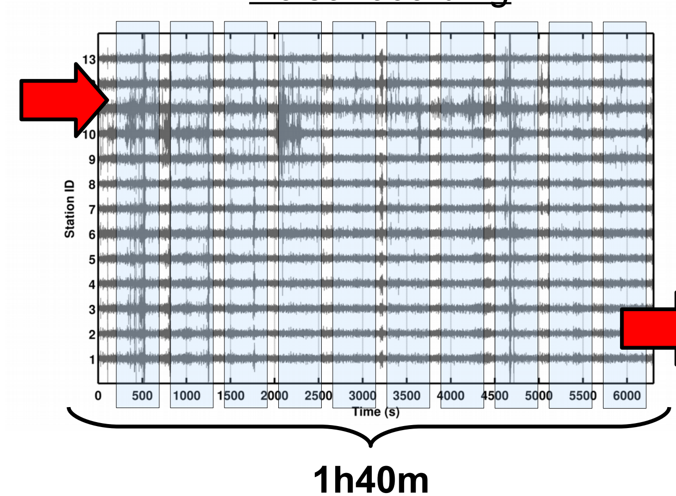
Ambient vibration seismology

(Array analysis)

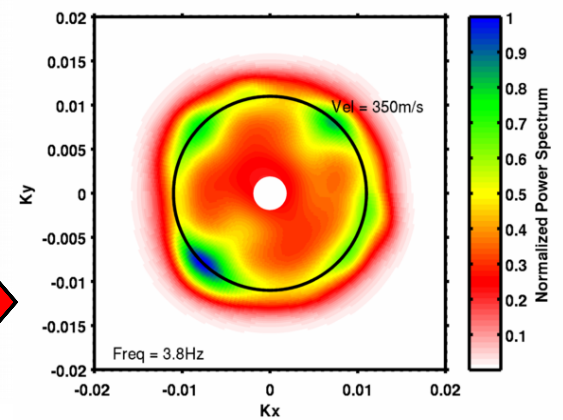
Array deployment

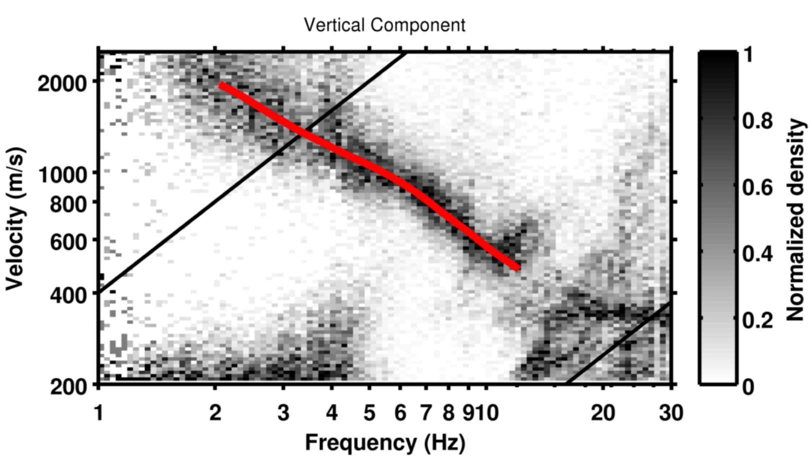


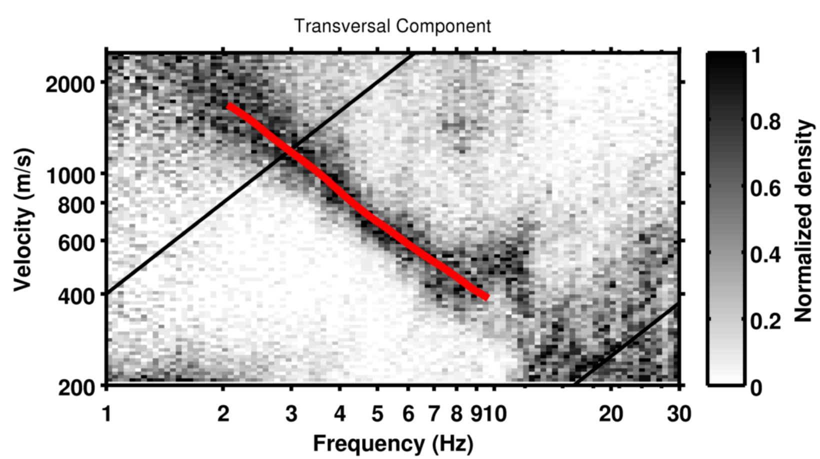
Noise recording



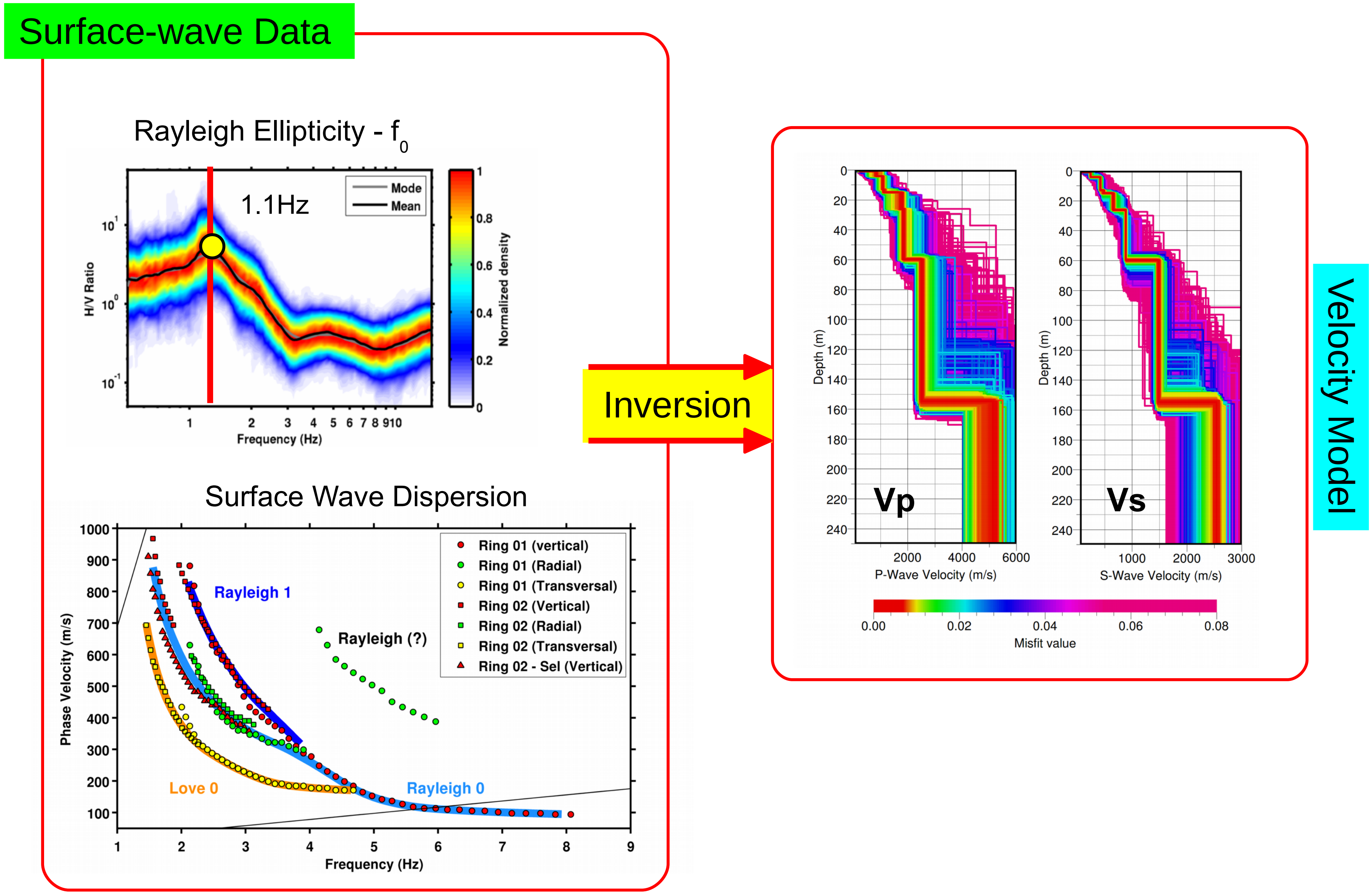
f-k analysis



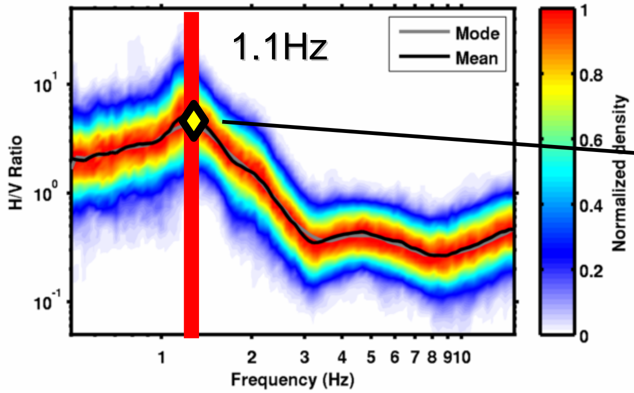


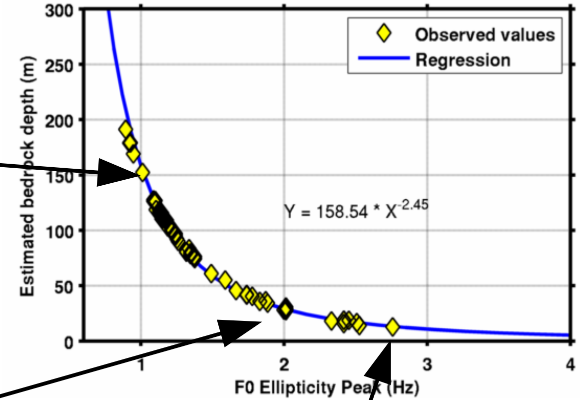


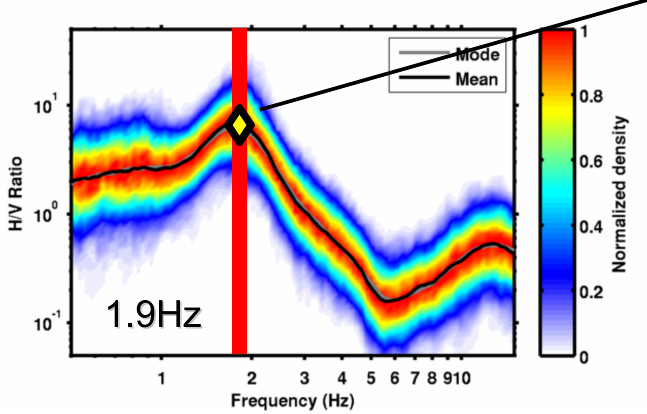
Building the Velocity Model

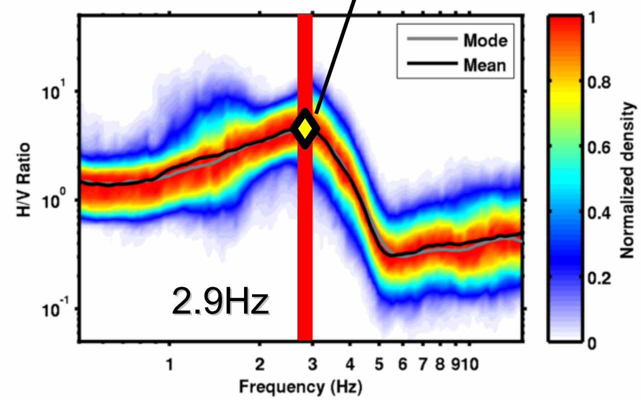


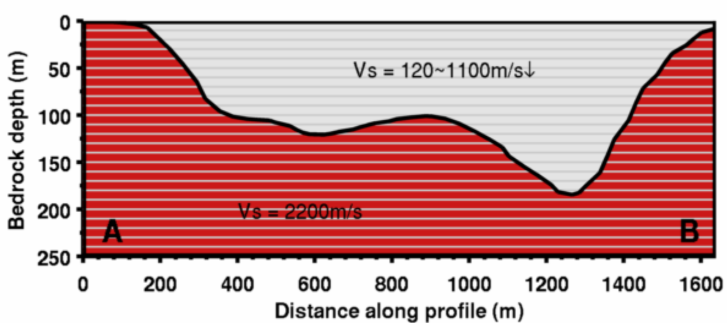
Defining the bedrock depth

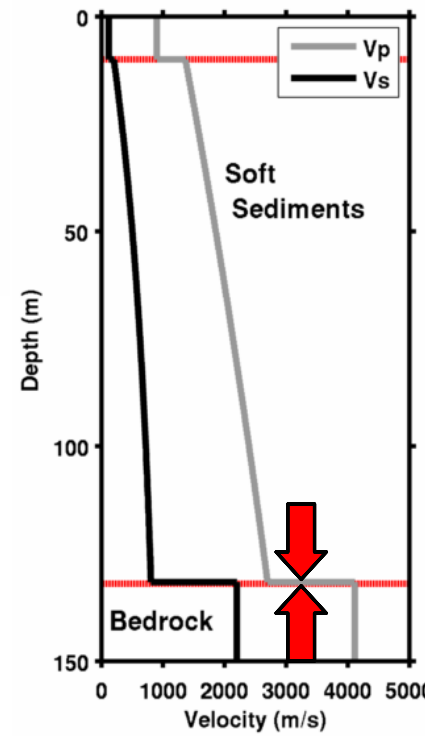




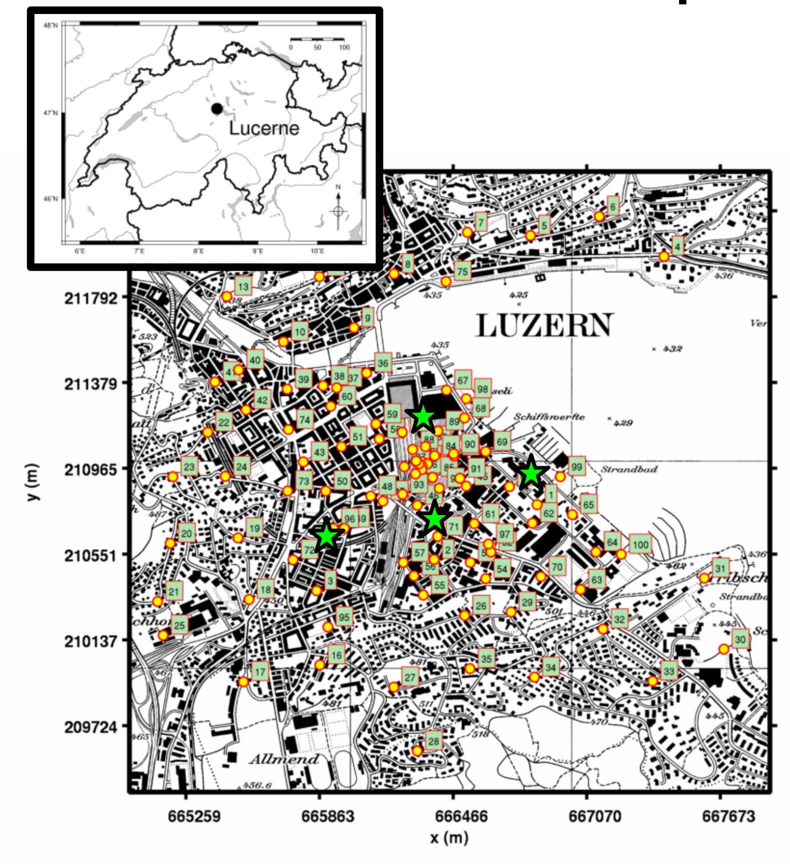




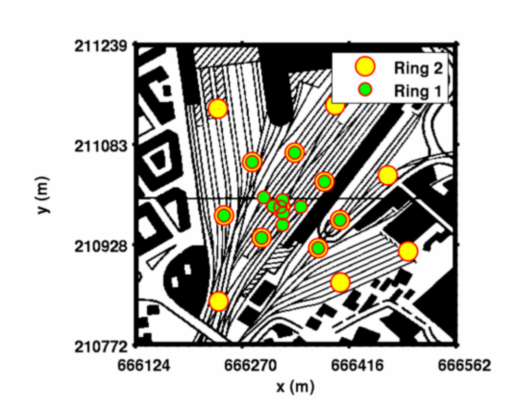




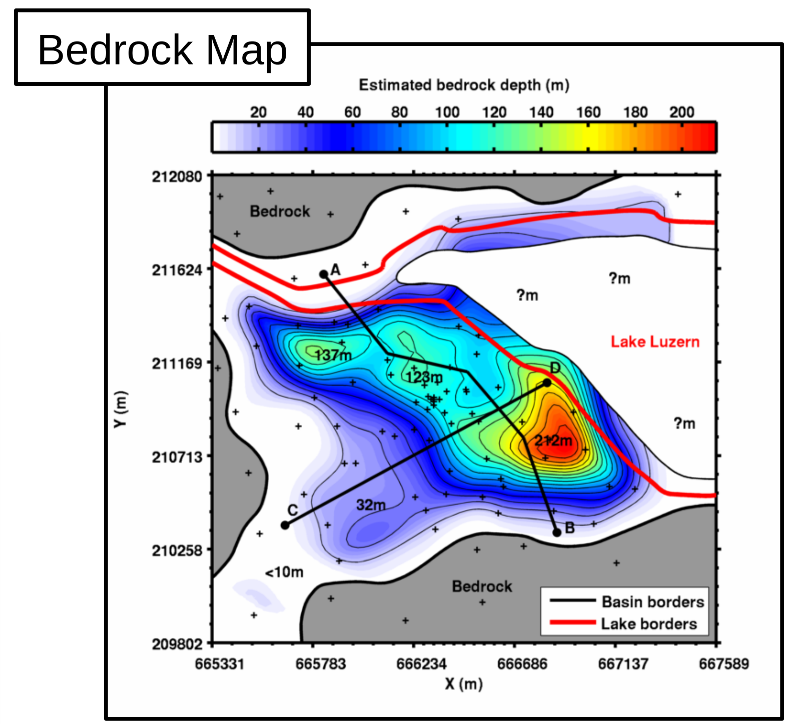
Example: Lucerne Microzonation



- > 100 single station measurements
- 4 array installations



Main array (~350m ⌀)



Mapping the SH-wave amplification

The 3d model consists of a horizontal grid of 100x100 soil columns. For each cell, a 1D SH-wave transfer function is computed.