Land Surface Waves:
A quantitative tool

E. Mouton, G. Durand and J. ADAMY
SISMOCEAN SAS - France

Geo2006 - Bahreïn
Geophysical Techniques on Land I

Introduction

Land surface wave: Rayleigh wave

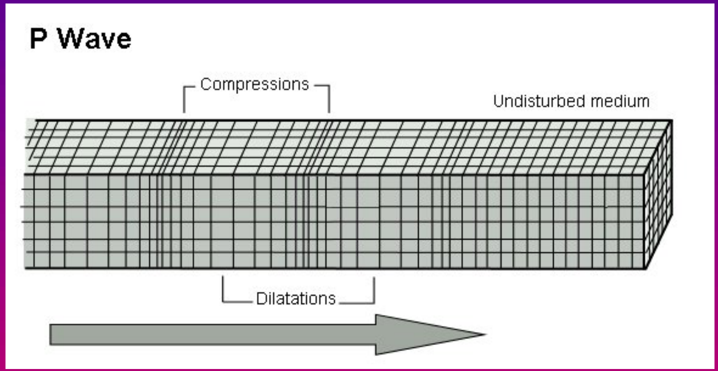
1) Properties

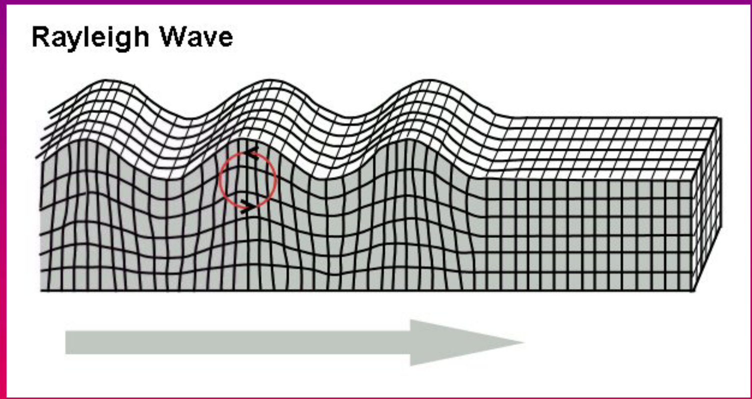
2) Numerical Inversion

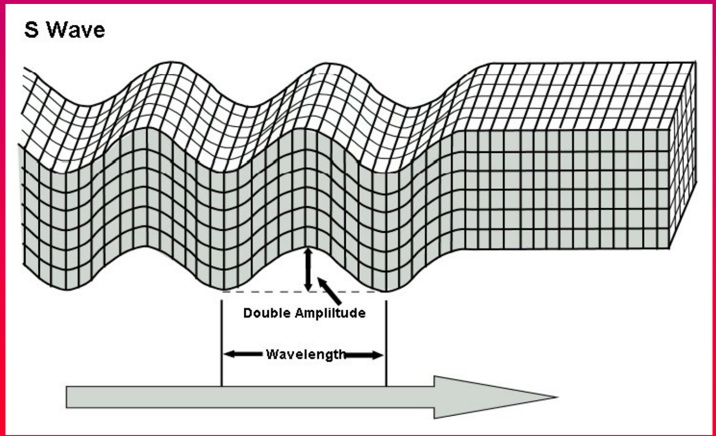
3) Results

Conclusion

Introduction







Equipments

Seismic recorder (3 Geodes MGOS)

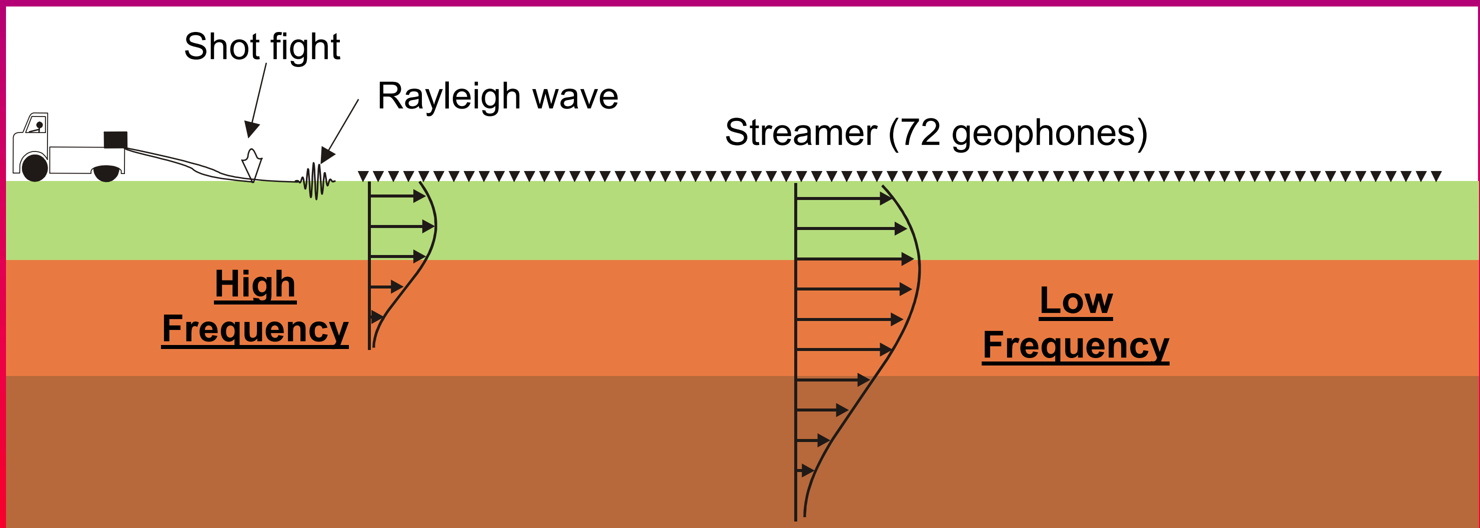
Streamer (72 geophones 4.5 Hz)

- 3 seismic recorders GEODES (3 x 24 channels)
- MGOS acquisition software
- 3 streamers for 24 receivers equally spaced from 1 to 3 meters
- 72 geophones 4.5hz (8 spares)
- Laptop
- Battery

Multichannels Acquisition Surface Wave (MASW)

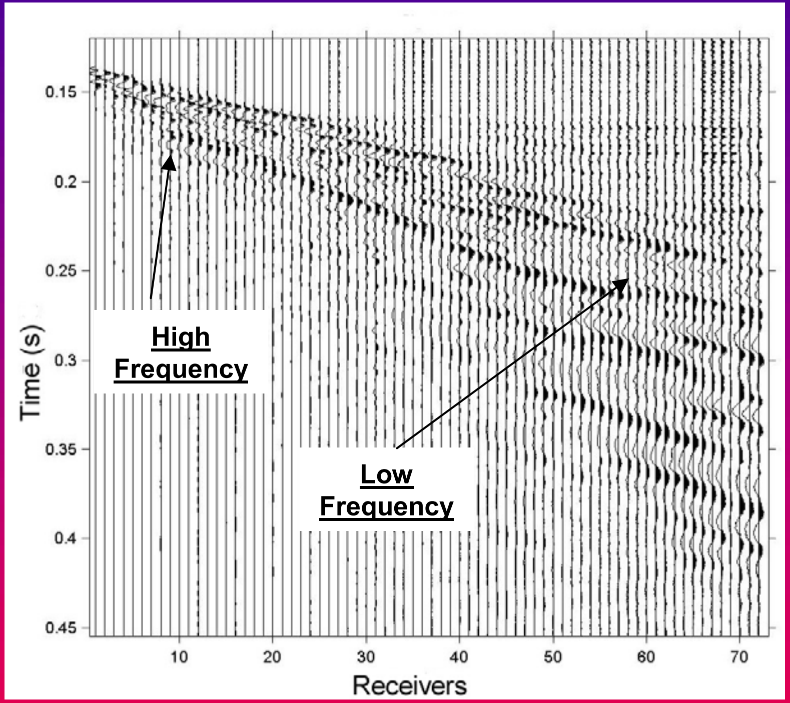
•The propagation is function of the geometry (layer thickness) and shear properties of the soil.

•The penetration is function of the wavelength



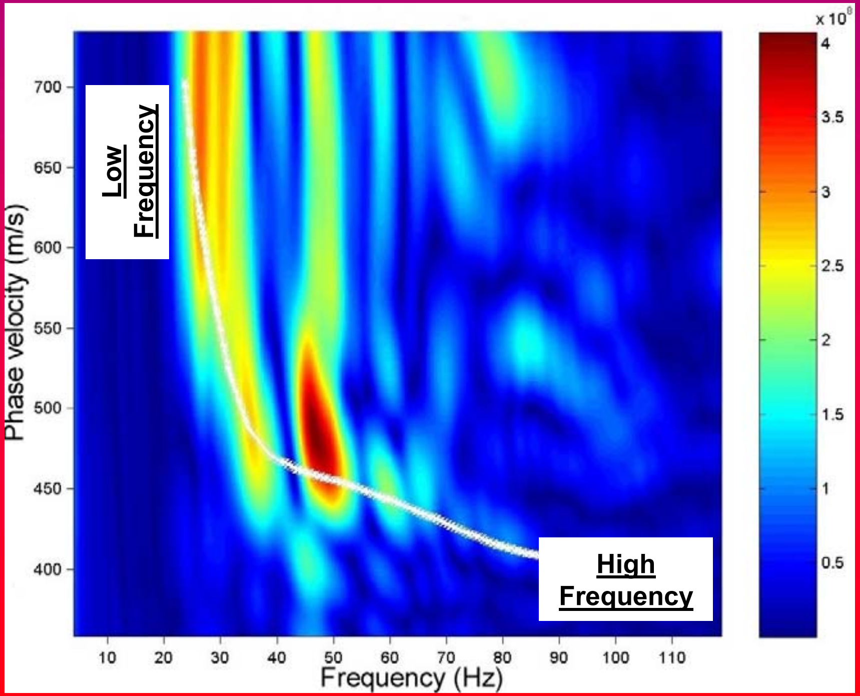
Land surface wave dispersion

Signal



P-tau transform or "slant stack"
(velocity spectral analysis)

Dispersivity



Numerical model

Layer 1 : ρ1 ; z1 ; Vp1 ; Vs1

Layer 2 : ρ2 ; z2 ; Vp2 ; Vs2

⋮

Layer i : ρi ; zi ; Vpi ; Vsi

⋮

Layer n : ρn ; zn ; Vpn ; Vsn

Substrate : ρ ; Vp ; Vs

Layer i :
- ρi : density
- zi : layer base position
- Vpi : P wave velocity
- Vsi : S wave velocity

Equations of continuity of displacement and stress lead to a system of equations. The resolution of this system give access to the model dispersive curve.

⇩

Automated inversion by iterative procedure minimize the difference between the theoretical and experimental dispersion curve

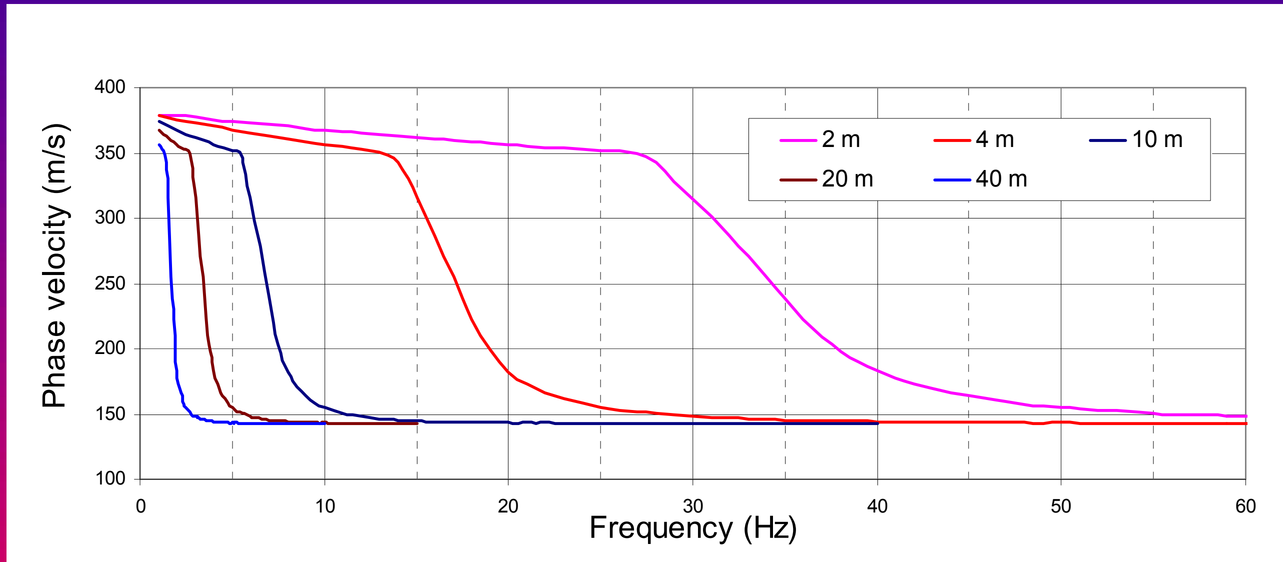
Major parameters (95%): thickness, shear wave velocity

Thickness variations

Thickness variations

Vp = 1000 m/s
Vs = 150 m/s
ρ = 1800 kg/m3

Vp = 2000 m/s
Vs = 400 m/s
ρ = 2000 kg/m3

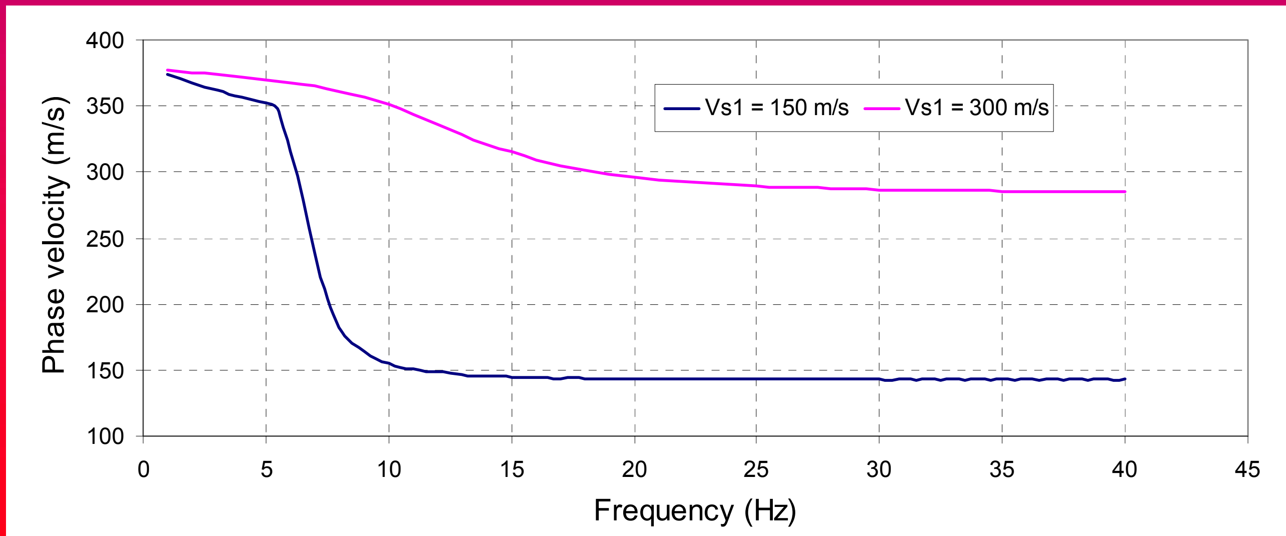


Vs1 variations

10 m

Vp = 1000 m/s
Vs = 150 /300 m/s
ρ = 1800 kg/m3

Vp = 2000 m/s
Vs = 400 m/s
ρ = 2000 kg/m3



Rayleigh surface waves:
summary of the main properties

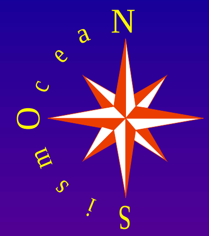
1) Major parameters :

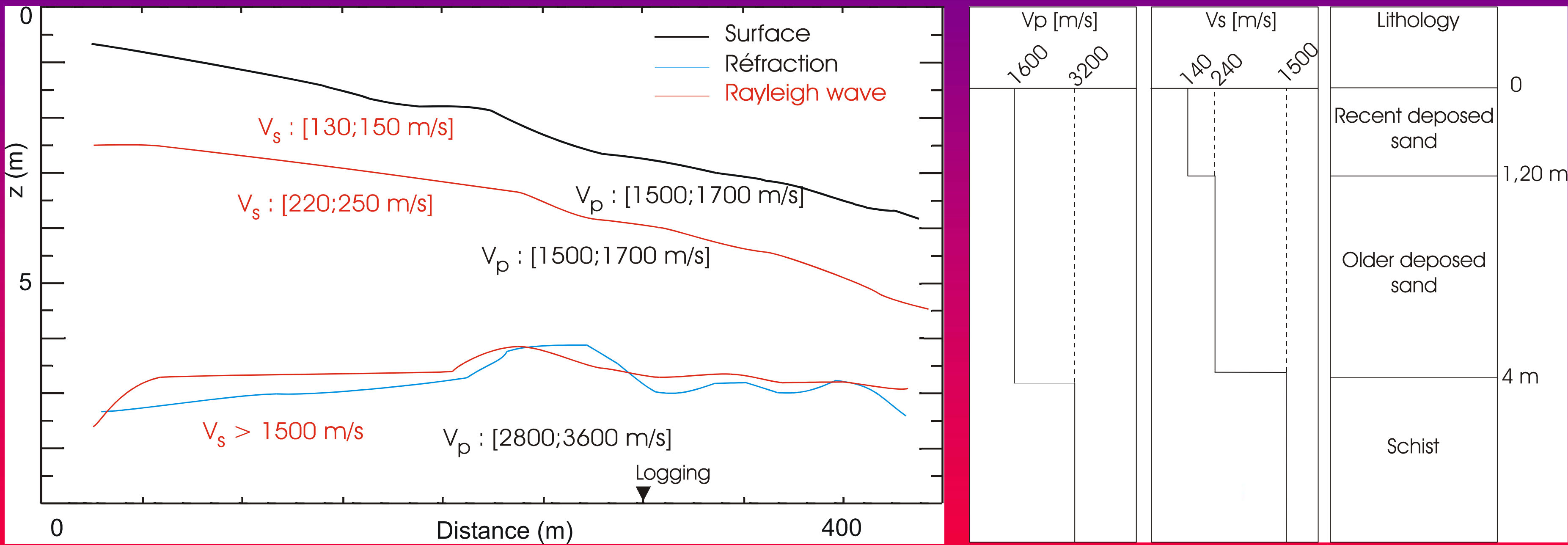
- layers thickness
- shear wave velocity

2) Depth investigation depends on the frequency range

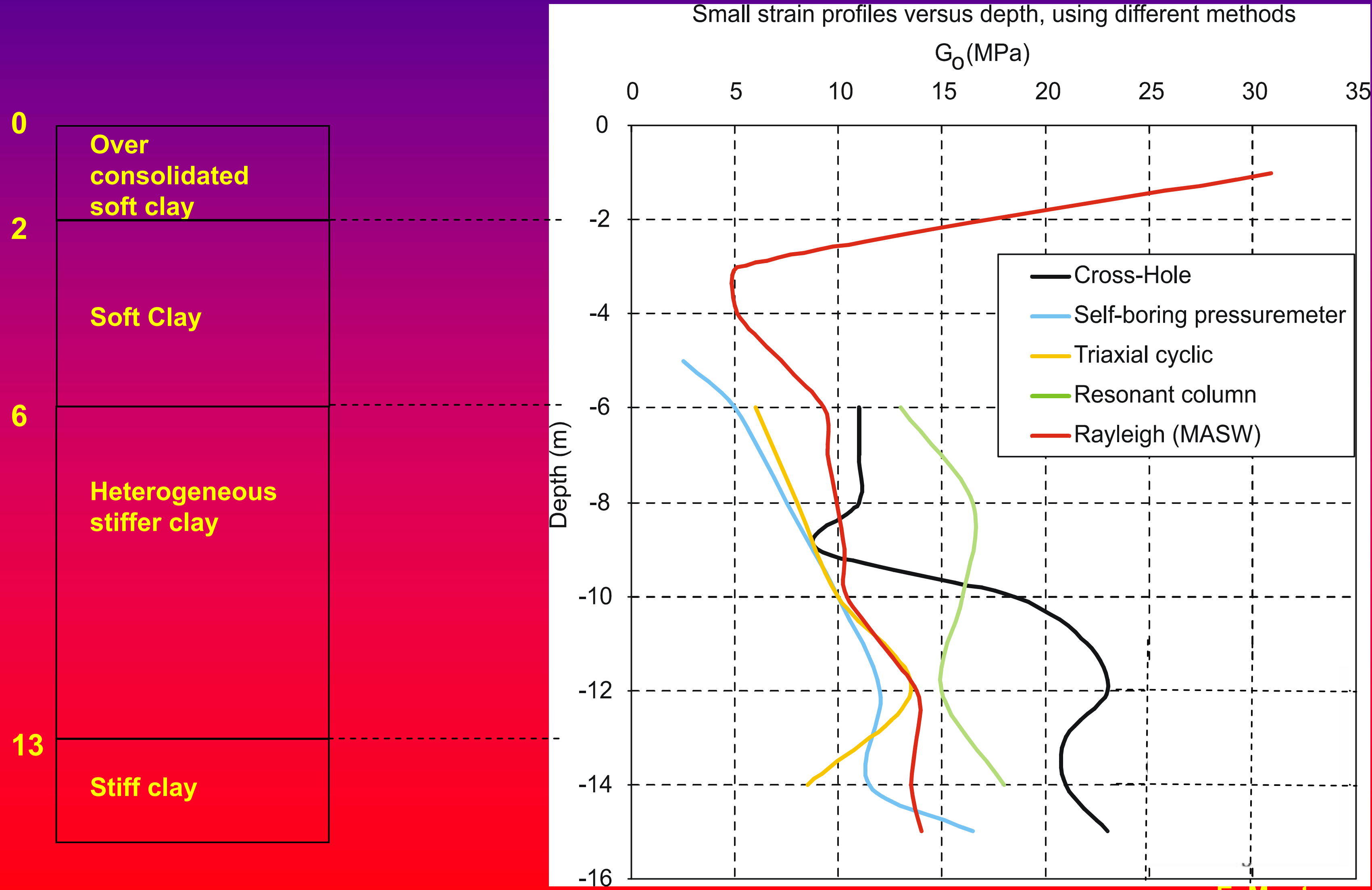
depth max # wavelength (λ) = interface wave velocity / frequency

Seismic refraction and MASW
(G and E modulus)



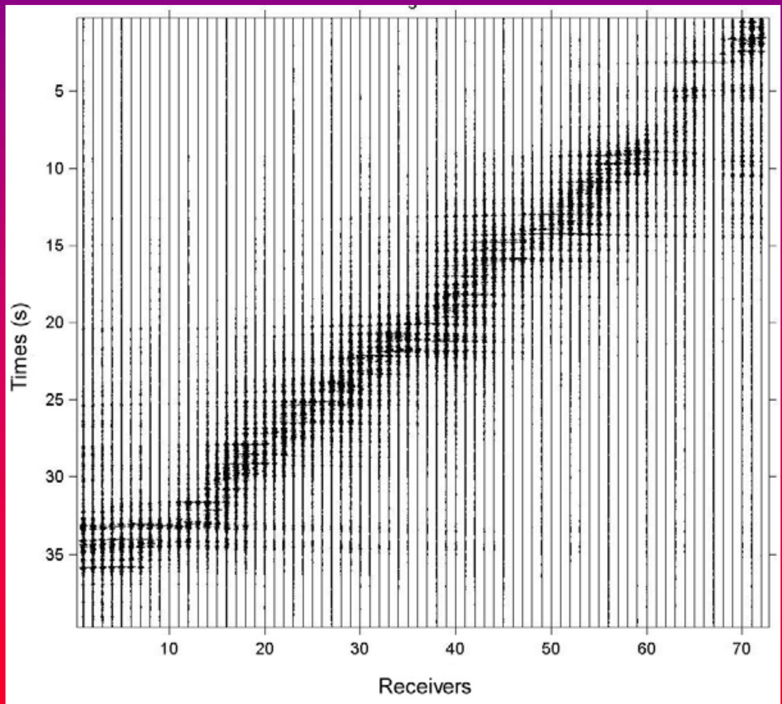


Small strain shear modulus G_o using different methods

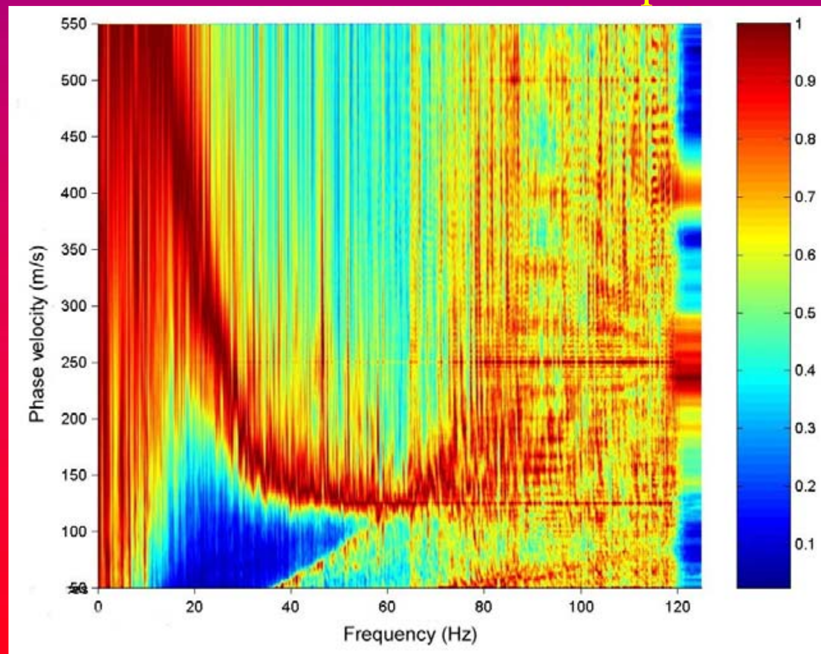


Micro tremor produced by a car

Signal

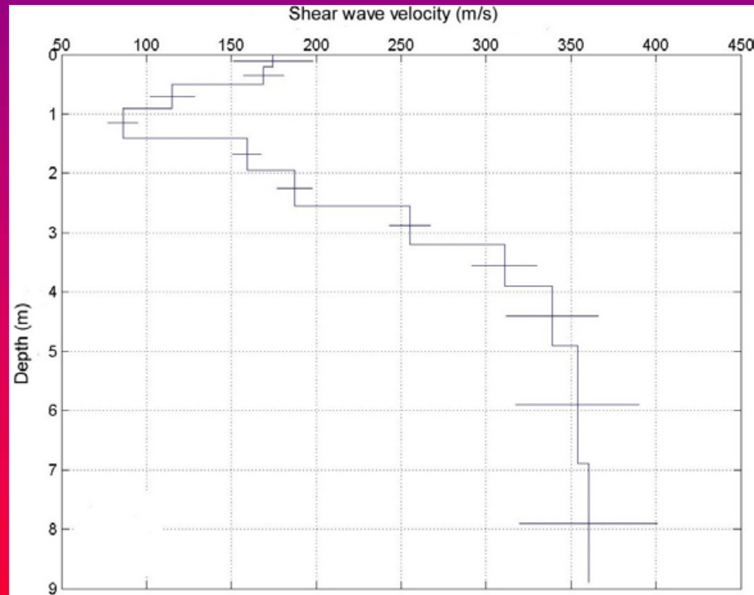


Dispersion



Interpretation using micro tremor

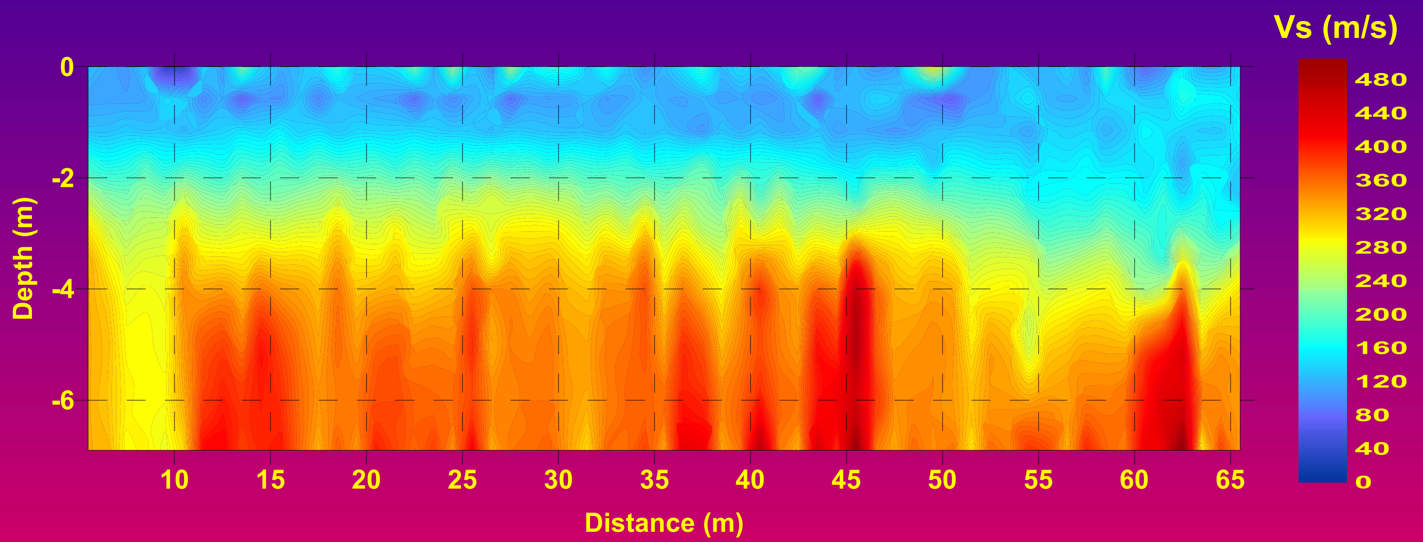
Vs (m/s) Function of depth



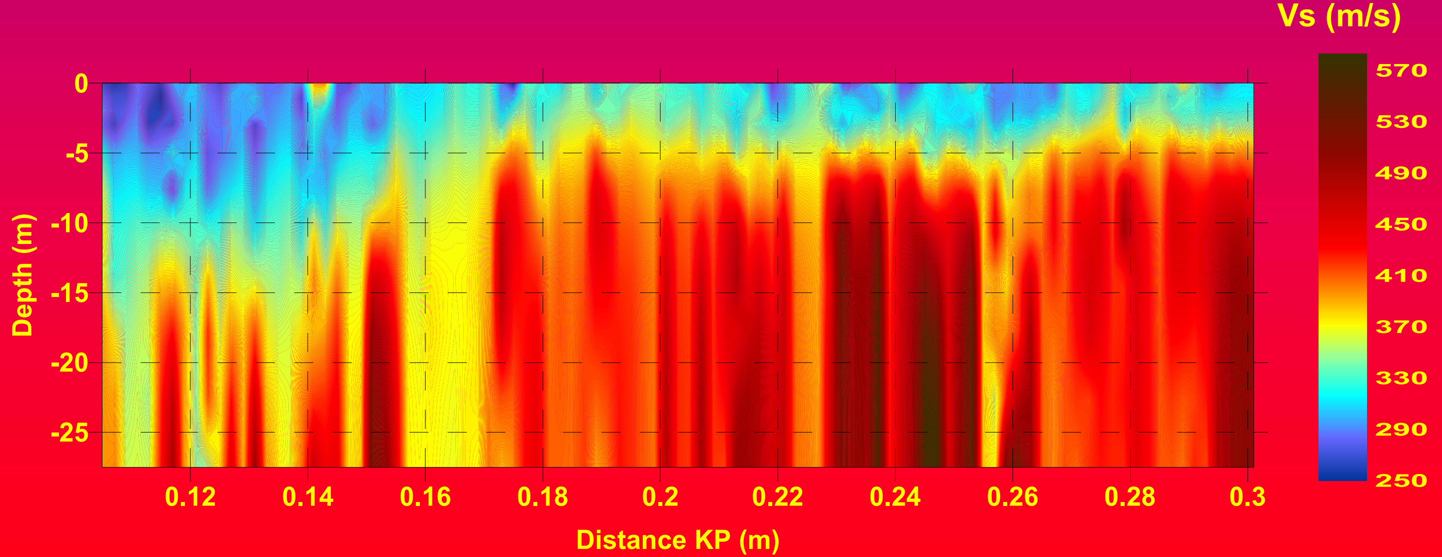
1 display using 72 receivers → **48 vertical Vs profiles**

2D Shear wave velocity profiles

Very shallow Penetration (1 display)
- **1 m**

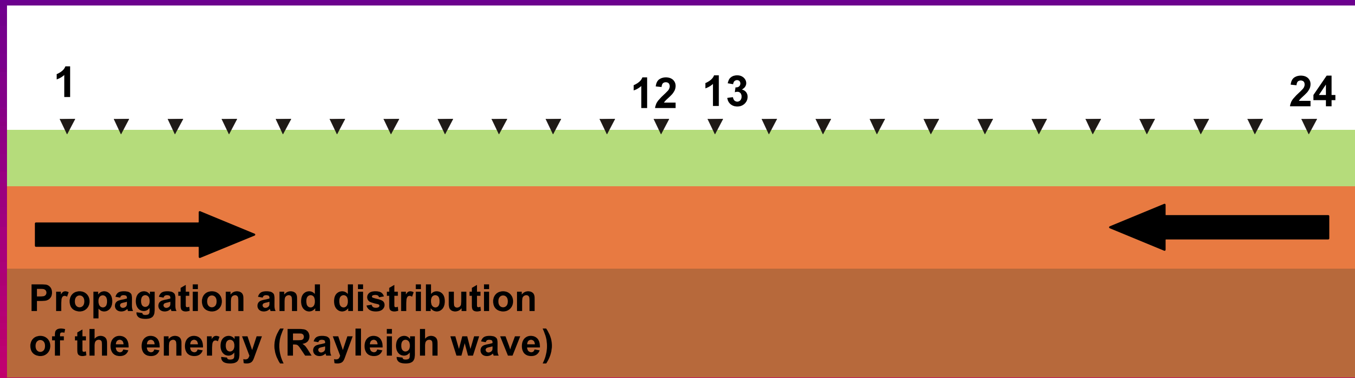


Shallow Penetration (3 displays)
- **2 m**

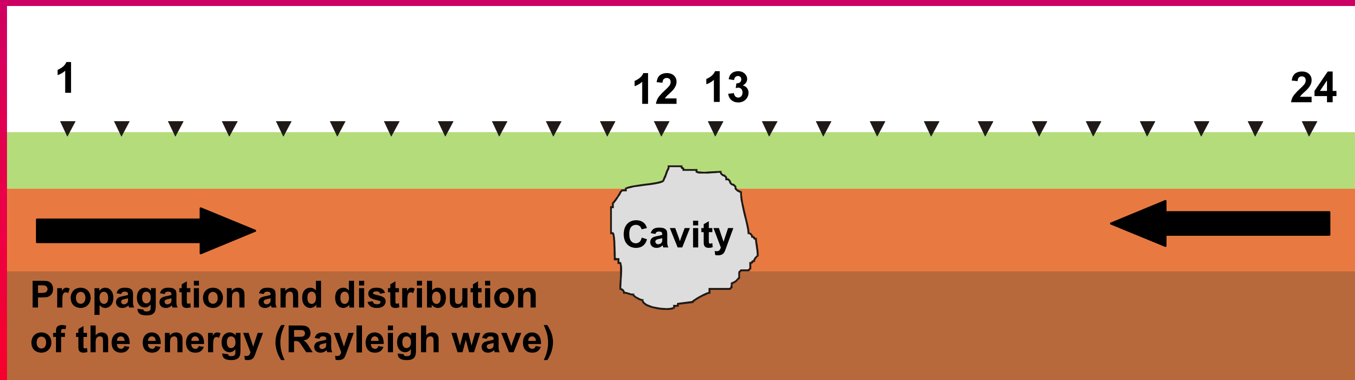


DCOS: Inhomogeneities detection (cavities, under consolidated soils)

Without inhomogeneity



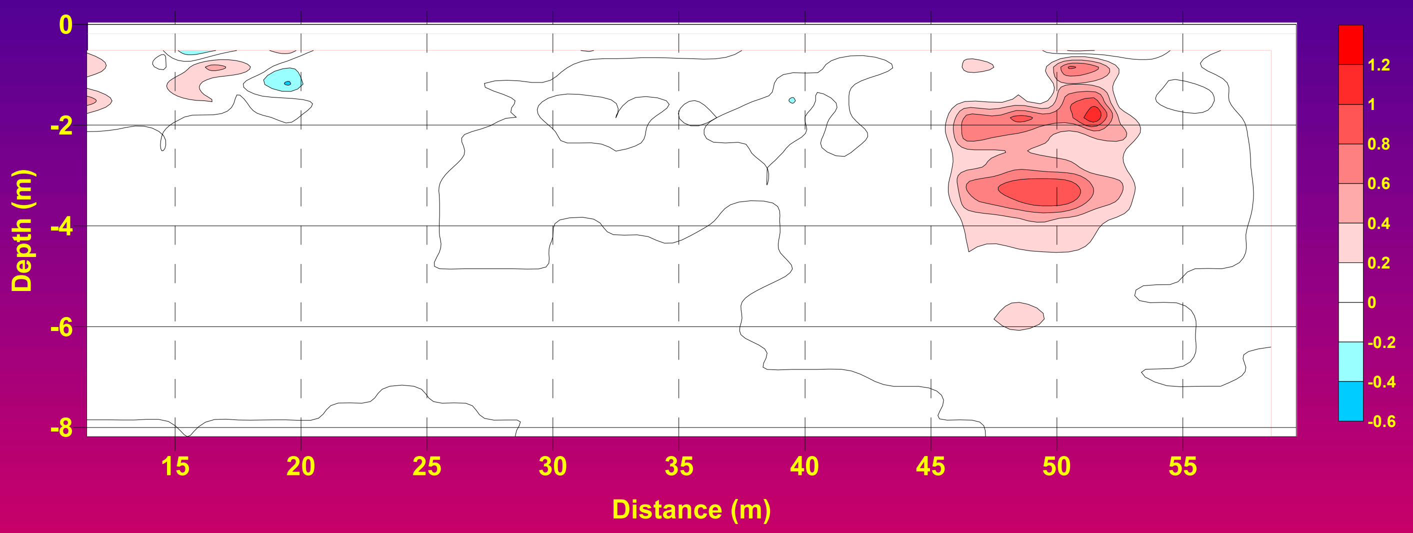
With an inhomogeneity



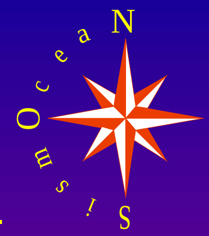
Analyse realised quickly and without any numerical inversions

DCOS results

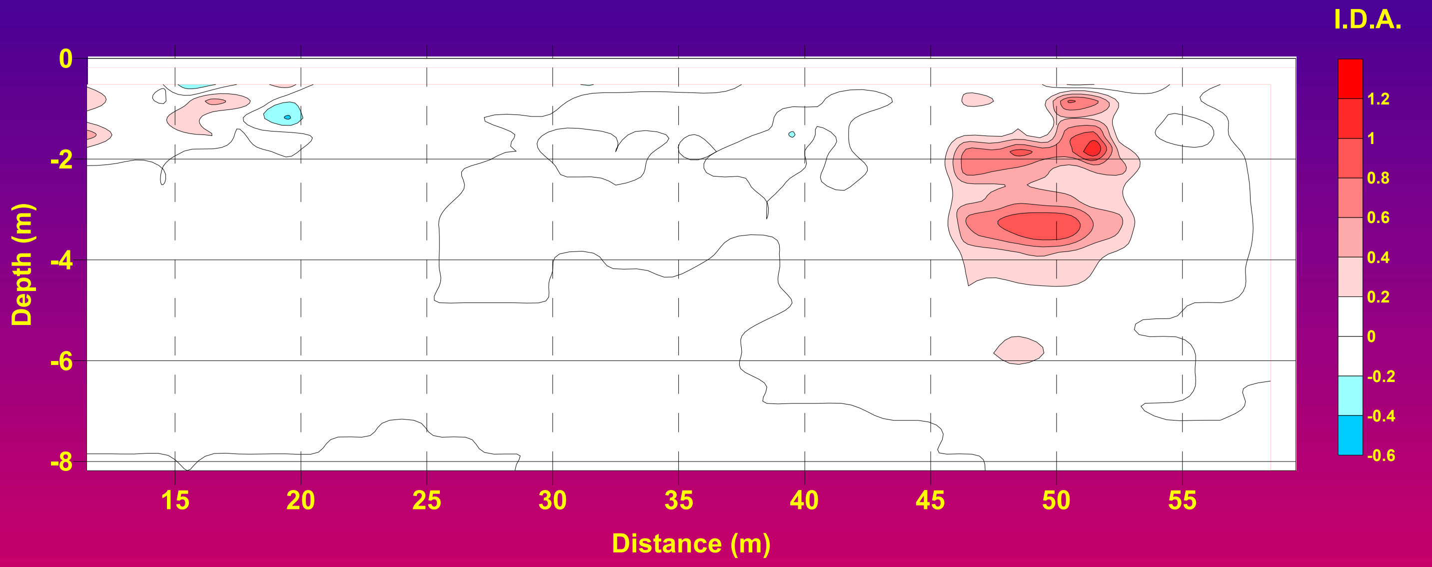
DCOS



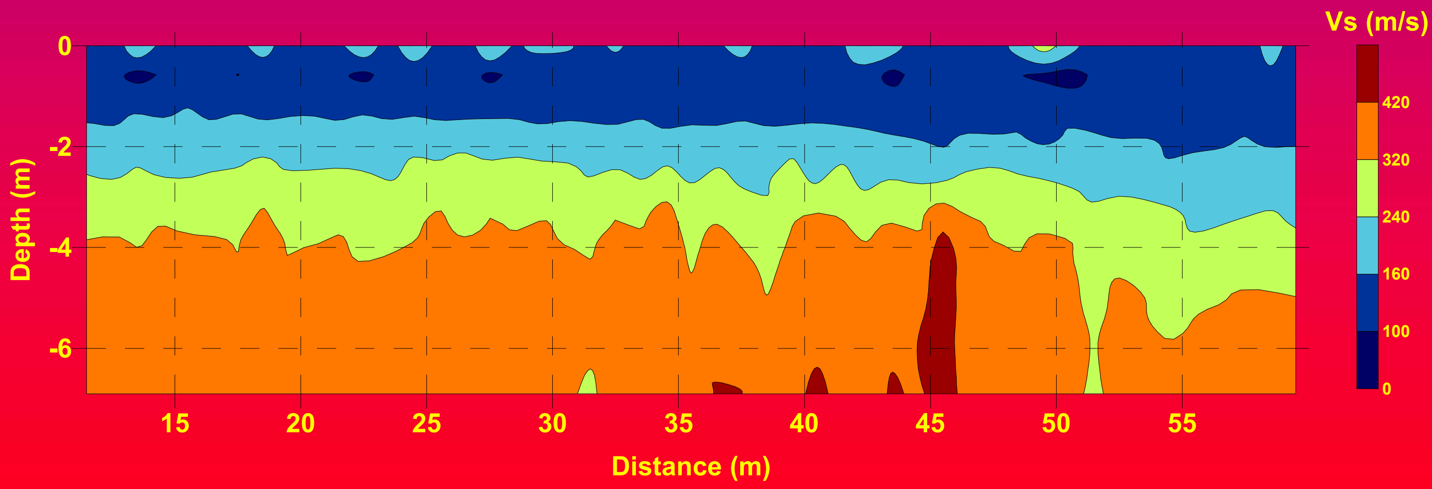
Combination of both DCOS and Vs results



DCOS



Vs (m/s)



Conclusion

- DCOS or Vs interpretation are non intrusive methods,
- Easy to adapt the display to the site
- Direct correlation with measurements using seismic cone, cross-hole and laboratory tests,
- Less expensive than the cross hole,
- Shear wave velocity inversions can be detected,
- Large survey area can performed using gimballed geophones,
- Different type of sources : hammer blow, dynamite or natural noise,
- Natural noise or micro tremor permit to work in noisy conditions (urban area, industrial plants),
- Using the micro tremor, cavities, under consolidated soil can be located.

Conclusion

Land surface wave survey (Vs profiles) and DCOS method are well adapted to qualify quickly a site :

- Pipeline route
- Check embankment or sea wall
- Development of industrial terminal : LNG…