Ambient Noise for hydrocarbon exploration

Introduction

Passive recording of seismic ambient noise can provide 1-D velocity profiles and therefore represent a low-cost and low-impact unconventional method in exploration to estimate:

- **Depth-to-basement**
- **Near surface velocity**

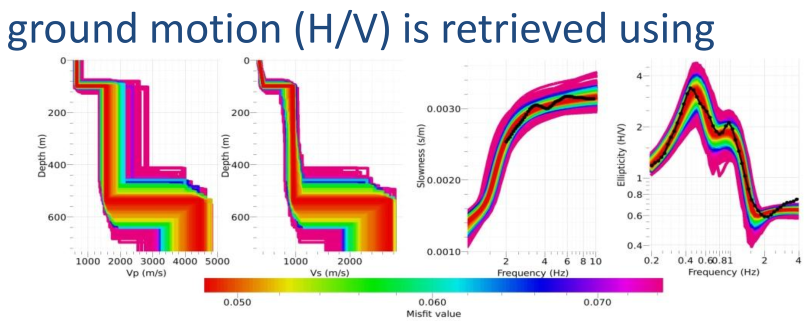
In exploration this is especially useful in:
- Unexplored areas
- Areas where conventional data are of low quality and need benchmarking
- Areas where access is limited
- Areas where seismic crews have left and additional information is required

The method

The method is based on surface wave inversion. Ellipticity and dispersive properties of the surface waves are jointly inverted to retrieve the ground velocity model. The results highlight the depth of the main velocity interfaces.

- Dispersion curve are retrieved using data recorded by an array.
- The ratio between the spectra of the horizontal and vertical ground motion (H/V) is retrieved using data recorded by a single station.

Steps:
1. Determine the dispersion curves
2. Retrieve the ellipticity of the Rayleigh waves (H/V)
3. The joint inversion of the H/V and dispersion curves (same weight given to both curves).
4. 1 D velocity profiles obtained from the best fit model



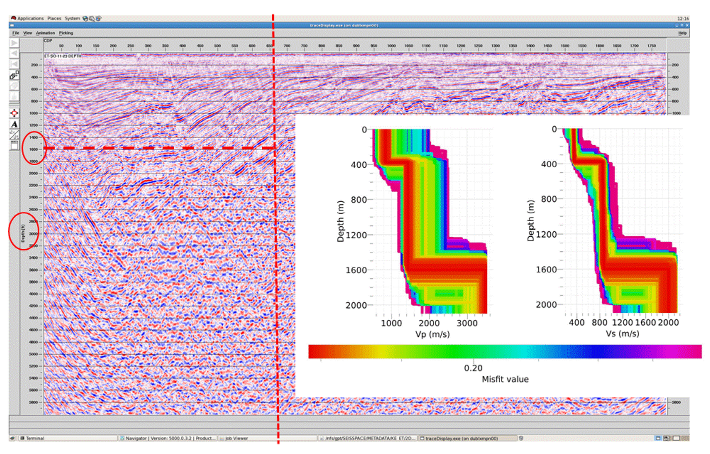
From left to Right: P-wave velocity model, S-wave velocity model; measured (black) and reconstructed (colours) dispersion and H/V curves.

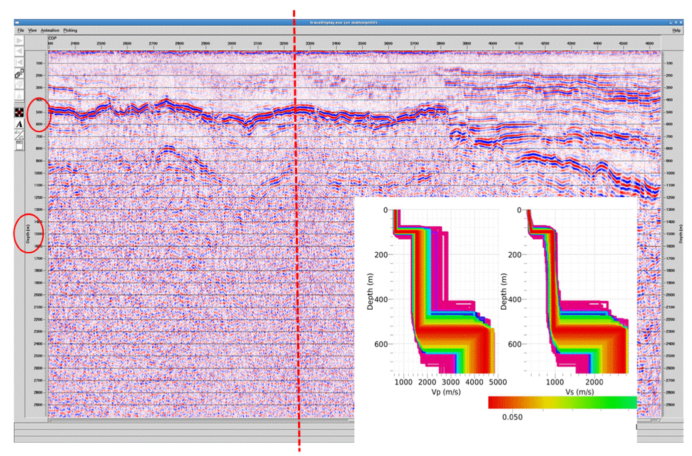
Depth to Basement

Aim: compare and integrate the basement depth obtained by passive seismic with estimates from the reflection seismic and MT data

1- Sedimentary basin

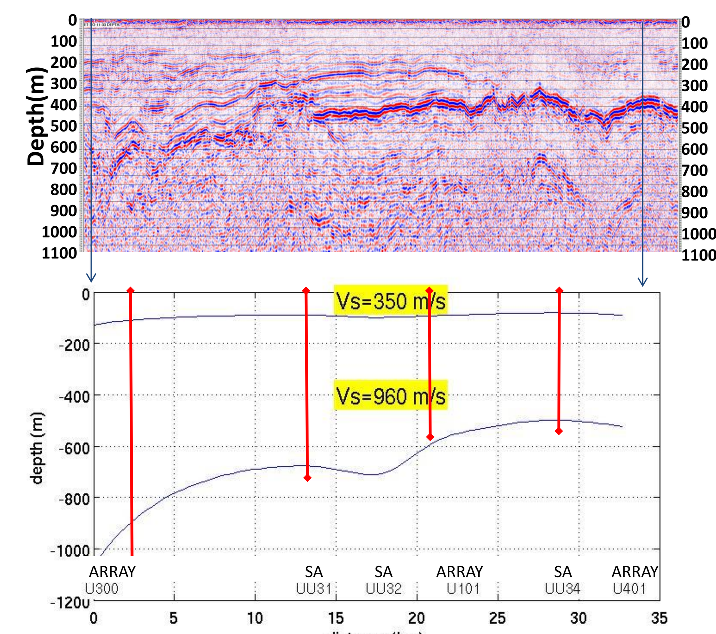
- Seismic
- Passive seismic





Comparison between active seismic profile and the 1D velocity model obtained by passive data inversion. Vertical red line indicates the position of the passive seismic station in relation to active seismic profile.

- MT data
- Seismic
- Passive seismic



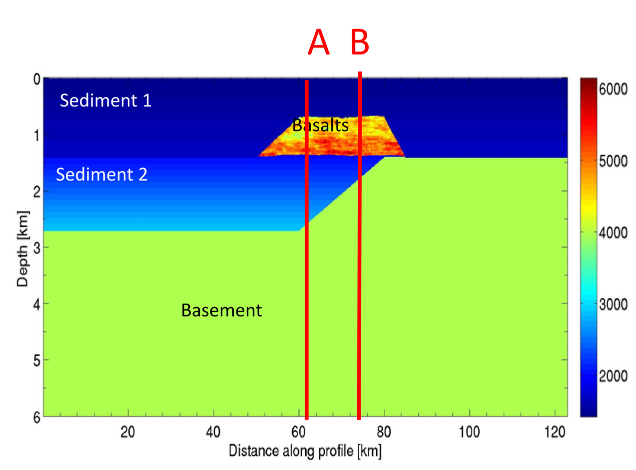
Passive seismic: interpolation of array results by stand alone stations. Results of the array inversions are used to constrain the S-wave velocities.

Profiles in blue derived by inversion of passive seismic; in red, depth to basement as derived by MT data for the four stations along the profile.

2- Complex environments: volcanics

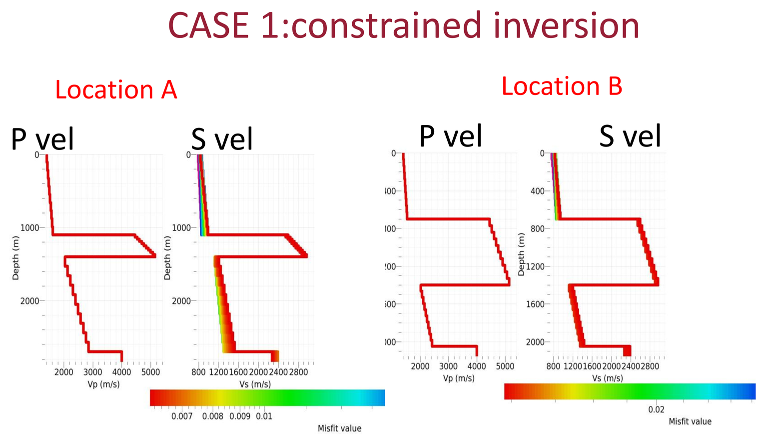
Aim: retrieve reliable depth-to-basement information in areas where volcanic rocks are present and have a detrimental effect on the quality of active seismic reflection data (e.g. the sub-basalt imaging issue in exploration)

Synthetic data:



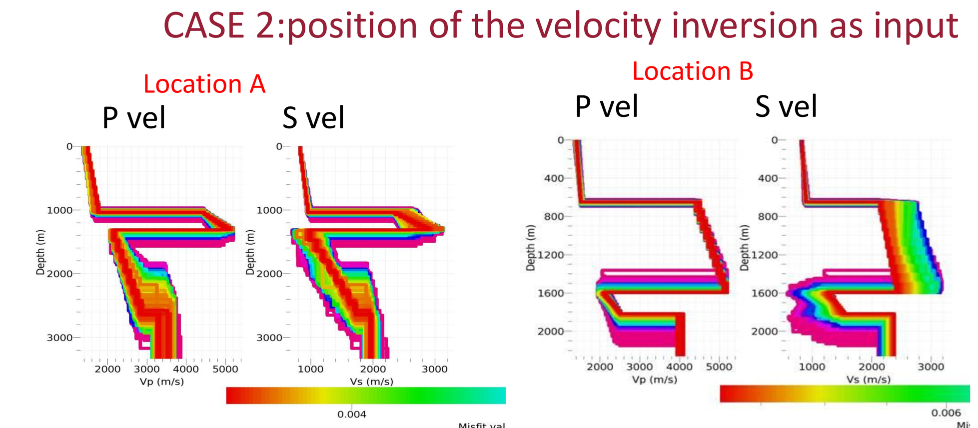
Synthetic velocity model with the 2 key locations where the joint inversion was performed.

CASE 1:constrained inversion



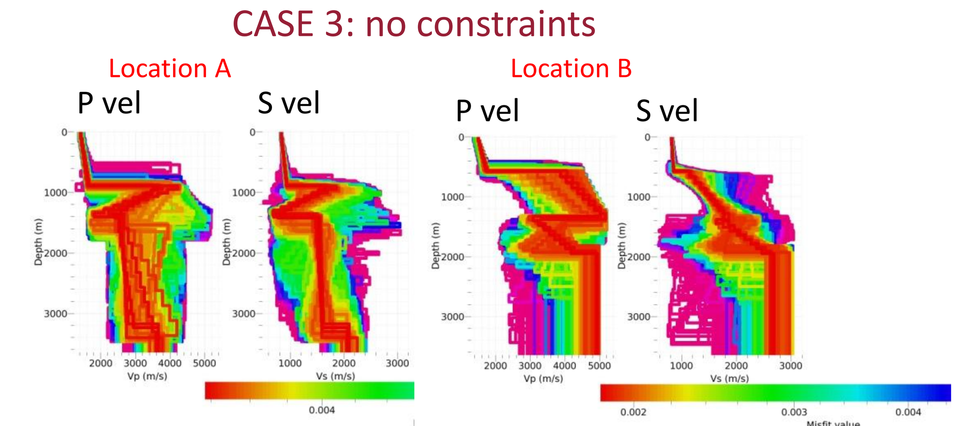
When P and S waves are used as constraints, the depth of the velocity interfaces are perfectly recovered.

CASE 2:position of the velocity inversion as input



When only the indication of the presence and position of the velocity inversion is given in input, the depths are well recovered.

CASE 3: no constraints



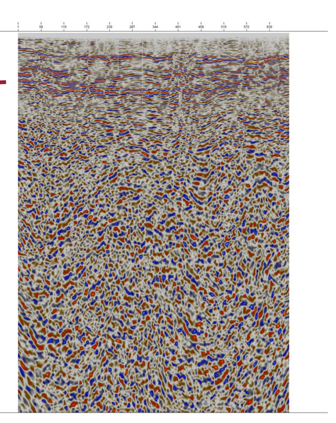
When no constraints are used, the depths are retrieved with larger error bars but with a reasonable accuracy.

The presence of the volcanics does not impinge upon the successful application of the passive seismic method. Without constraints the results are still qualitatively correct, even allowing for errors on the depth estimates. Some constraints are needed in the inversion in order to obtain reliable results.

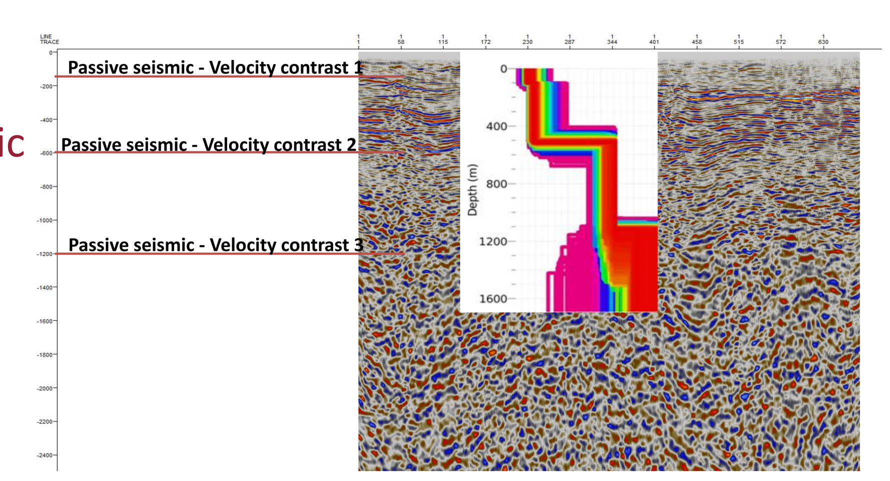
Real data: **Aim: integrate the depth-to-basement obtained by passive seismic within Grav-Mag data inversion, to benchmark depth-to-basement in poor-quality active reflection seismic data**

Two bright reflectors, loss of coherency below

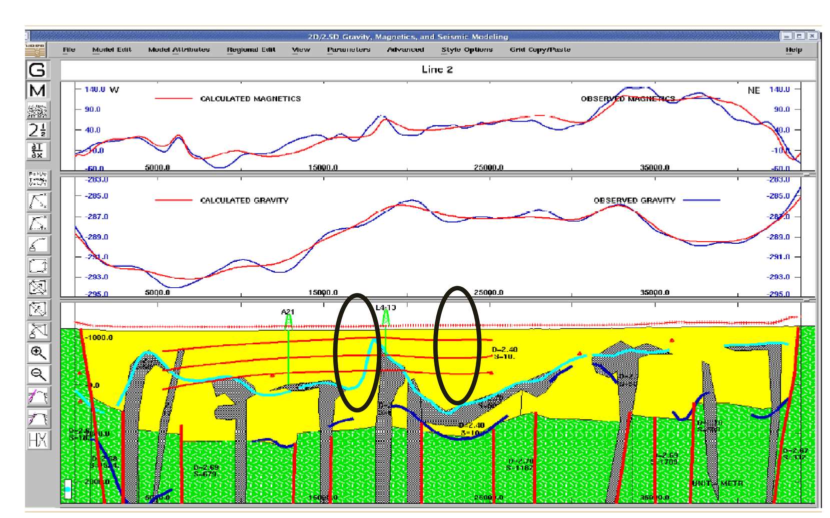
Is this depth to basement or is the basin deeper than that?



- Seismic
- Passive seismic



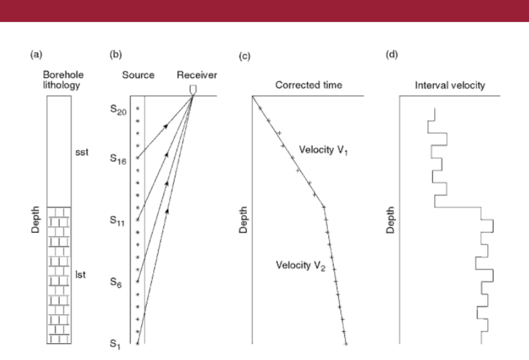
- Seismic
- Passive seismic
- Grav/mag data



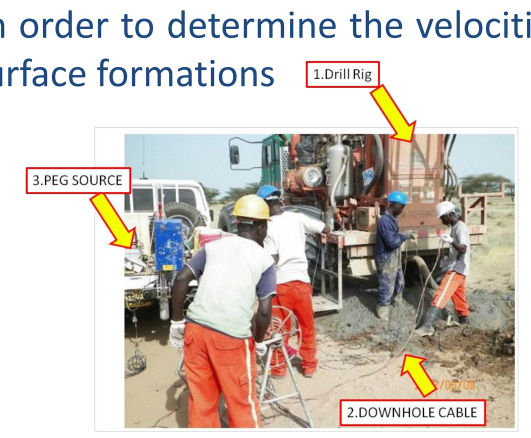
Correspondence of the depth of the strong reflectors between the sills (cyan line in the Grav-Mag model), the passive seismic results (green lines) and vintage seismic profiles (red lines).

Near surface

Aim: evaluate if passive seismic can be used to determine the near surface (<100m) velocity model.

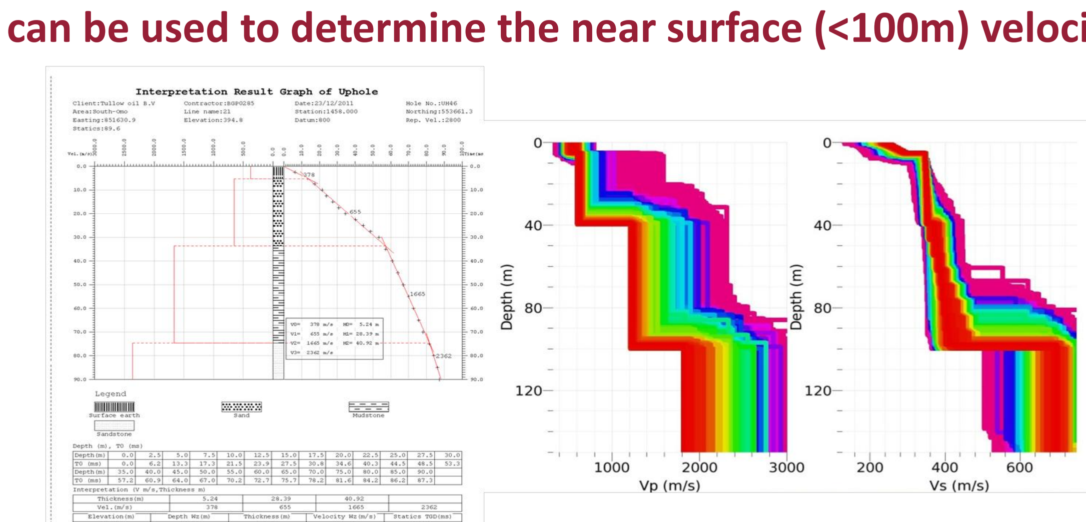


Uphole survey:
- Successive sources at varying depths in a borehole in order to determine the velocities of the near-surface formations



- Acquired at line intersections during active seismic survey.
- Important information but expensive.

- Small denser (for shallower resolution) arrays at line intersections where upholes have been acquired.
- Is passive seismic a valid method to in-fill uphole information?



Comparison between the uphole information and the first layers of the 1D velocity model obtained with passive seismic data joint inversion. The joint inversion is able to replicate the information of the uphole.

Good correspondence between the interfaces highlighted by the up-holes and the ones retrieved by the inversion of passive seismic data.

Conclusions

1. Passive recording of seismic ambient noise analysis is able to resolve the structure of a basin.
2. The depth-to-basement values obtained through passive seismic data match active seismic and other non-seismic data.
3. In complex environments, as when volcanic layers are present, results can be considered qualitatively correct (i.e. deeper/ less deep basements), with error bars in the order of hundreds of metres. Resolution is improved when some constraints are given to the inversion.
4. Near surface velocities obtained through passive seismic data analysis are remarkably similar to the ones from upholes acquired during the seismic program at the same location. Therefore the method can be used to in-fill between upholes to reduce survey costs or to obtain shallow velocities where and when upholes acquisition is not possible..

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