Surface-wave analysis for pseudo-2D Vs profiling on a granite-micaschists contact at Plœmeur hydrological observatory, France

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Seismic methods are proposed here in a crystalline context to characterize mechanical properties of aquifer systems and delineate fractured and weathered areas. The joint interpretation of pressure (P) and shear (SH) wave velocities (Vp and Vs), along with electrical resistivity (ρ), helps us to characterize both weathered layer and substratum. We worked on a well-instrumented experimental site to develop an optimal acquisition methodology to perform simultaneously P-wave refraction tomography and surface-wave profiling. Surface-wave dispersion was extracted from shot gathers with offset moving windows and stacking techniques, then inverted to retrieve a pseudo-2D Vs profile. Vs obtained from both surface-wave profiling (VsSWP) and SH-wave refraction tomography (VsTOMO) were compared to validate the best-suitable parameters for inversion of surface-wave dispersion.

I. Geological context

WHERE? Plœmeur (Morbihan, France): contact between granite (West) and micaschists (East). Several pumping wells producing water at a rate of 10⁶ m³ per year since 1991 (Ruelle et al., 2010).

WHY? To characterize the mechanical properties of the subsurface in the contact zone.

II. Prospection methodology

HOW? - 476 m profile intersecting the contact zone
- Simultaneous P-wave refraction tomography and surface-wave profiling
- SH-wave refraction tomography
- Electrical Resistivity Tomography

WHY? - Vp-Vs comparison (e.g. Olona et al., 2010)
- Validation of VsSWP with VsTOMO, Vp and ρ (Pasquet et al. NSG-EAGE, 2012)

III. Electrical Resistivity Tomography

Wenner-Schlumberger – 96 electrodes – 4 m spacing – 1 roll-along

Interpreted limits for geological structures:
1- Granite
2- Weathered granite
3- Clays
4- Micaschists possible contact zone

IV. P- and SH-wave tomography

WET inversion (Schuster & Quintus-Bosz, 1993) with n iterations. Convergence criterion based on trace RMS mean (μRMS) and standard deviation (σRMS) values:

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\mu_{RMS}/\sigma_{RMS} < 0.01 \% \quad \text{and} \quad \sigma_{RMS}/\mu_{RMS} < 0.01 \%
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V. Surface-wave profiling

Dispersion extraction: offset moving window to narrow down lateral extent of dispersion measurements; stacking to improve signal/noise ratio and enhance higher modes (e.g. Neduca, 2007).

Dispersion inversion: 1D inversion with a Neighborhood Algorithm (Wathelet et al., 2004) at each Xmid; average best models within the error bars we selected; 2D VsSWP section reconstruction (Boiero & Socco, 2010).

VI. Conclusions

Simultaneous P-wave tomography and surface-wave profiling have been performed on a well-instrumented and monitored site. The main geological structures delineated by ERT are visible with seismic tomography and surface-wave profiling, but the contact zone is not clearly defined.

On a methodological point of view, VsSWP shows good agreement with VsTOMO:
- the 6-trace window gives the best lateral resolution;
- the 12-trace window gives the best investigation depth;
- the 24-trace window do not return lateral variations;
- shear-wave contrasts are well-imaged, but absolute values of Vs are different.

Surface-wave profiling provides a satisfying image of the lateral variation of shear-wave velocities, but further methodological developments are required to take advantage of redundant data and direct-inverse shots implementation.

References
Pasquet et al. [2012] in NSG-EAGE, Paris
Neduca [2007] Geophysics, 72(2)
Wathelet et al. [2004] Near Surface Geophysics, 2(4)

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