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Surface wave dispersion analysis in hard rock sites: challenges and opportunities

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Analysis of surface wave (SW) dispersion data is widely used for exploring the subsurface at various scales. More than 95% of published examples, however, refer to soft sites characterized by soil layers. In these conditions, SW exhibit smooth, broadband, often multimodal dispersion patterns. On stiff sites, characterized by very thin overburden above shallow or even outcropping rocks, SW data become noisy and higher modes can prevail over the fundamental mode (Bergamo et al., 2011). Moreover, local fractures and heterogeneities can generate scattering and back reflections in a certain frequency band (Pileggi et al., 2011). On the other hand, high phase velocities of rock materials produce long wavelengths that make the investigation depth significant also for band limited data.

We show using synthetic and real data from a hard rock mining site the typical spectral patterns that can be expected on hard rock sites and the effect of having or not having a thin soft overburden with high impedance contrast with the underlying bedrock. In case of overburden, two well separated dispersive wavetrains are generated on top and on bottom of the overburden. The slow event generated on top of the overburden follows the theoretical fundamental mode of Rayleigh waves, while the fast event generated at the top of the hard rock coincides with the theoretical first higher mode. They can be separated and muted both in t-x domain and in f-k or f-v domains. For outcropping rock, the slow event is not present and a poorly dispersive high-energy event is generated. This propagation mode is very similar to the higher mode in case of overburden and corresponds to the fundamental mode of Rayleigh wave propagation. The clear interpretation of the nature of dispersive events is of paramount importance for their inversion.

We present a processing workflow based on muting and multi-stage inversion to handle hard rock SW data and obtain reliable pseudo-2D VS models. Spectral energy vs. offset is used to identify different environments for wave propagation (Colombero et al, 2018) and a method based on skin depth of surface wave (Socco and Comina, 2017) is used to estimate Poisson's ratio and transform the VS models into VP models. This leads to a comprehensive site characterization in hard rock environments using surface wave data.

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