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EFFECT OF THE UNDERGROUND STRUCTURE ON THE WAVE-FIELD: THE HIGH-RESOLUTION EXPERIMENT IN CEPHALONIA ISLAND (GREECE)

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From September 2011 to April 2012, a large seismological experiment took place in the high seismicity area of Cephalonia Island (Greece) within the FP7 EU-NERA 2010-2014 project (Network of European Research Infrastructures for Earthquake Risk Assessment and Mitigation). Cephalonia Island, the largest of the Ionian Islands in western Greece is located at the northwesternmost boundary of the Aegean plate, which is dominated by the Cephalonia Transform Fault (Scordilis et l., 1985).

More than 60 seismic stations were deployed along a profile crossing the 1.5 x 2.2 km shallow sedimentary basin of Argostoli, with inter-station distance of about 50 meters. Two very dense arrays (minimum inter-station distance of 5 meters, maximum inter-station distance of 150m) were also established close to the northeastern basin edge and in the basin center (Figure 1).

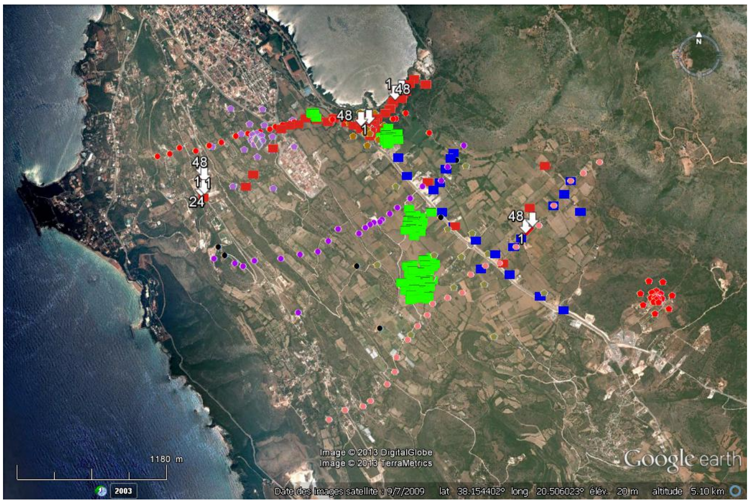

Figure 1. Experiment deployment: seismological stations (red squares), noise single-stations (blue squares), microtremor array (green squares), MASW (arrows), noise single-stations of SINAPS@ (red, purple and pink circles)

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This network recorded about 700 local, regional and teleseismic earthquakes with magnitudes larger than 2 and good signal-to-noise ratio. The basin was selected as being representative of shallow extended basins with large impedance contrast and a pronounced 2D symmetry. The experiment was aimed at: i) checking the extent of the area surrounding seismological stations where the seismic response is stable in order to relate observations to the near-surface structure and layer geometry including lateral variations, and ii) providing vertical velocity profiles, which are the basic information needed to interpret observed amplifications through numerical modeling.

Preliminary data analysis (Cultrera et al., 2014) indicates large multidimensional site effects inside the basin (amplification from 5 to 10 over the 1.5-8 Hz frequency range) together with a large spatial variability of ground motion within few tens of meters inside the basin. These effects are associated with a significant proportion of Rayleigh and Love surface waves in the seismic wavefield, which generate large spatial ground motion variability over short distances, together with a local scattering coming primarily from the southwest of the basin (Imitiaz et al., 2014).

The interpretation of the recorded wave-field required a deep investigation of the geological and geotechnical characteristics of valley. To this aim, geophysical experiments (including passive and/or active surface wave measurements and single-station measurements) and a detailed geological survey were conducted in cooperation with the SINAPS@ French project.

The geophysical surveys consisted of different kind of measurements (Figure 1): i) MASW measurements using 48 4.5 Hz geophones connected to two Geodes manufactured by Geometrics. Profile lengths ranged from 47 to 70.5 m and seismic signal was induced using a 5 kg hammer. Typical shot offsets were 5, 10 and 20 m at both side of the profile, and a shot at the centre of the profile; ii) array noise measurements; iii) single-station noise measurements.

Rayleigh waves dispersion curves derived at the arrays in the basin has been computed by different teams and with different techniques: FK frequency-wavenumber and SPAC spatial autocorrelation techniques on noise array, and the Multiple Signal Characterization algorithm MUSIQUE on earthquake array data (Imitiaz et al., 2014). The results are rather consistent (Figure 2). S-wave velocity results were obtained by inversion analyses, following a joint inversion scheme using Rayleigh and Love wave dispersion curves and Horizontal-to-Vertical spectral ratio curves. The best-fit S-wave velocity profile for the northeastern basin edge and the basin center is characterized by a significant impedance contrast at about 40 meters (Figure 2).

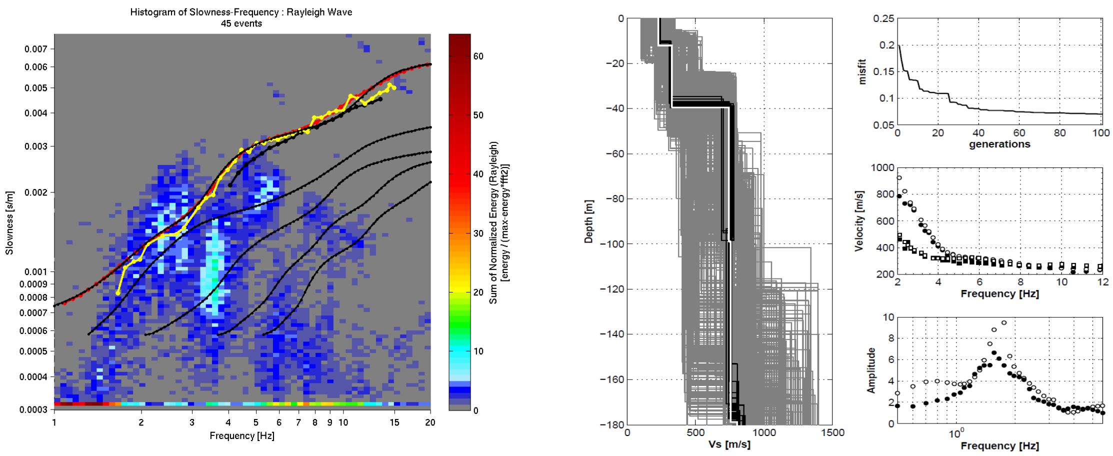

Figure 2. (Left) Love and Raileigh dispersion curves: 3 component SPAC (yellow); 3 component F-K, MASW results and vertical component SPAC (Red); 3 component F-K other mode (black dot), 3 component MUSIQUE from earthquake analysis (color map), theoretical model from inverted S-wave profile, 0 to 4 modes (black thin lines).
(Right) a) S-wave velocity profile from the joint inversion; best fit model (white line), models in a range of the best fit model + 10% (black lines), all models (gray lines), b) misfit for all 150 generations, c) observed (black circles) and calculated (open circles) Rayleigh wave dispersion curve, observed (black squares) and calculated (open squares) Love wave dispersion curve, d) observed (black circles) and calculated (white circles) H/V spectral ratio

A preliminary version of the geological map of the Argostoli region has been realized using field observations, fault and bedding measurements and available boreholes (with depths ranging from 36 to 260 m) drilled for water exploration (Figure 3). Together with the single-station noise measurements, used to compute the resonance frequency from Horizontal-to-Vertical spectral ratios (HVN), is possible to limit the depth of the main seismological discontinuities (Figure 3).

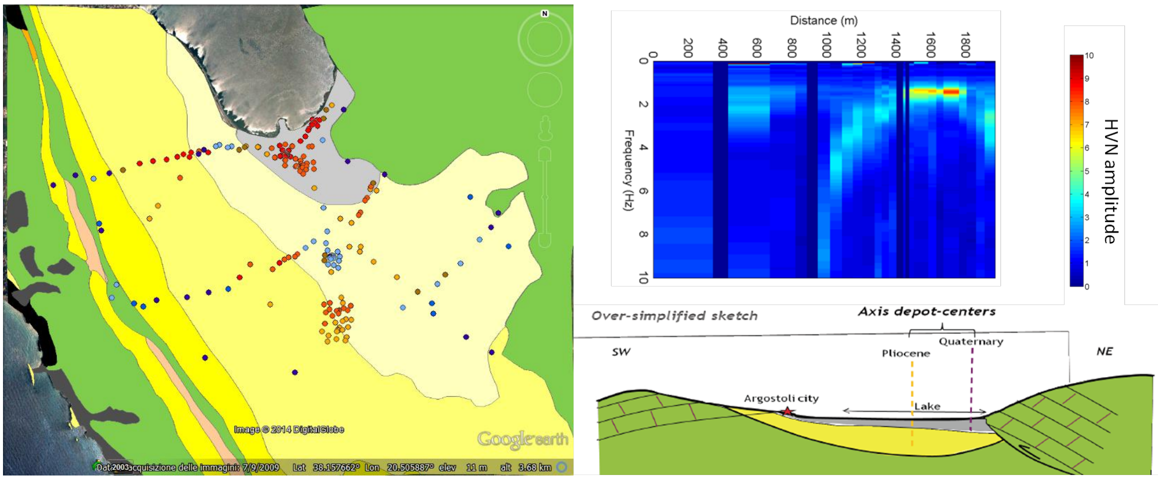

Figure 3. (Left) Map of the main geological boundaries: gray (present to recent Quaternary deposits), light yellow (Pliocene sands), dark yellow (Pliocene calcarenites), orange (Eocene limestones), green (lower Cretaceous limestones). Dots represent the resonance frequency (f_o) from H/V on noise: red (f_o<1.6), orange (1.6≤ f_o<2.0), yellow (2.0≤f_o<2.6), dark yellow-mustard (2.6≤ f_o<3.0), azure (3.0≤ f_o<5.0), blue (5.0≤ f_o<10), dark blue (f_o≥10).
(Right) First attempt for a cross-section compared with the HVN amplification (North component).

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