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3D VS MODELING FROM HIGH-FREQUENCY AMBIENT NOISE TOMOGRAPHY: THE CASE OF NORTHERN MYGDONIA BASIN, EUROSEISTEST AREA (NORTHERN GREECE)

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The main target of the present work is to investigate the applicability of noise cross-correlation for shallow site characterization on local scales. For this reason and following the approach adopted in regional applications, we have extracted Rayleigh wave traveltimes from noise correlation traces in order to perform surface wave tomography, resulting in the determination of group velocity maps for different frequencies. Since the interpretation of these group velocity maps is not as straight-forward as for phase-velocity information (e.g. Pilz et al., 2012), we employ a node based dispersion curve inversion to derive a 3D shear wave velocity model for the northern part of the Mygdonia basin (N.Greece). The basin is a Neogene graben structure with significant seismic activity along distinct normal faults with E-W, NW-SE, and NE-SW directions (e.g. Vamvakaris et al., 2006, see fig.1.). The sediments consist of two main units, the lower pre-Mygdonian system (mainly conglomerates, sandstones, silt/sand sediments and red beds), and the upper Mygdonian system (Quaternary formations, mainly sandy conglomerates and silt/sand alternations), with a maximum thickness of ~500m that overlay the gneiss-schist basement. The central Mygdonia area hosts Euroseistest, a European Test site, where a large number of studies have been performed (e.g. Jongmans et al., 1998; Raptakis et al., 2000), focusing mainly along a 2D model profile with a NNW-SSE direction. The geological setting of the area (e.g. neotectonic faults, bedrock outcrops, etc.) suggests that despite its dominant 2D basin characteristics, the presence of 3D geological structural features is also expected.

We have focused in the northern part of the Euroseistest area, which includes almost all the observed Mygdonia basin formations, ranging from the bedrock outcrop in the North and reaching the Holocene deposits in the central part of the basin (see fig. 1). For the data collection, we used a pool of 27 instruments, consisting of 19 fixed position stations and 8 mobile units (WARAN pool, Ohrnberger et al., 2006). Using this setup, it was possible to improve the ray coverage of the study area, while using an instrument pool that could be easily managed by a small number of operators in the field. As a first step, we extracted the Rayleigh wave traveltimes from the vertical component cross-correlation traces of the collected noise seismic recordings, using the processing approach of Bensen et al. (2007). Cross-correlations were computed for all possible station pairs (~1400 pairs), assuming that correlation traces are dominated by surface waves, hence allowing the estimation of the traveltimes of Rayleigh waves for all frequencies and each station pair (e.g. Campillo and Paul, 2003).

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The obtained Rayleigh wave traveltimes showed significant spatial, distance and frequency variability, as they were clearly affected by the dominantly 2D structure of the study area. In general, the southern and northern paths clearly show much higher and lower slowness values, respectively. This observed large velocity increase from North to South and the rather strong 2D (north-south) traveltime variability is in very good agreement with the expected mainly 2D pattern of local geology, as the northern bedrock formations are expected to exhibit higher group velocities.

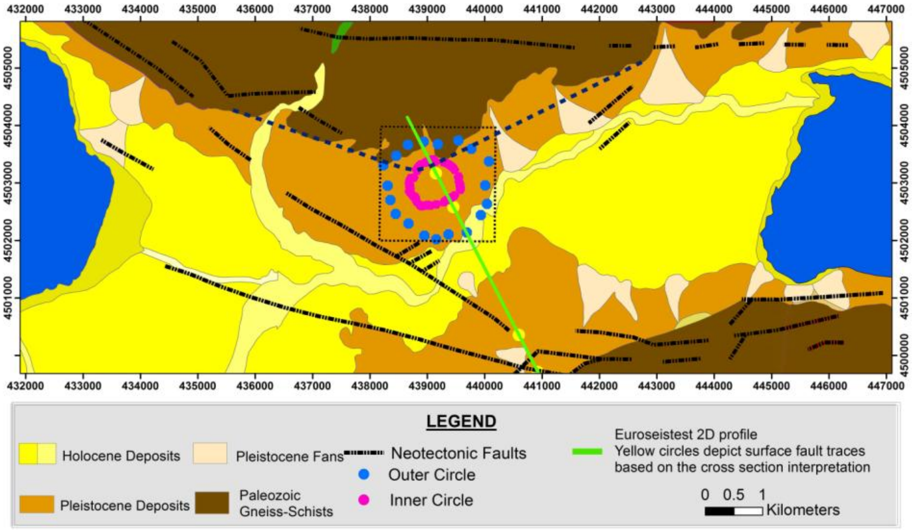

Figure 1. Schematic geological map of the central Mygdonia basin. The two measurement circles of the study area (thin dashed line) are depicted by blue and red circles. The Euroseistest profile and the surface projection of the main faults along this profile are shown by a green line and yellow circles, respectively. Coordinates correspond to the Greek Cartographic System (EGSA87). The blue-dashed line depicts the dominant strike of the bedrock-sediments northern boundary.

The final traveltime dataset was tomographically inverted, using a modified inversion approach that involved approximate Fresnel volumes, spatial smoothing constraints for each frequency and inter-frequency smoothing constraints, introduced with an appropriate second Laplacian operator in the linearized tomographic system. Moreover, we adopted an iterative data-rejection procedure, in order to reject outlier traveltimes (e.g. higher modes erroneously picked as fundamental modes). The resulting group velocity maps (Fig. 2) are presented for 2 typical frequencies, considering only nodes with adequate ray coverage, hence fulfilling minimum resolution and error criteria. A very consistent pattern is observed, with higher velocities in the northern bedrock area and lower velocities for the southern part, where the Neogene-Quaternary sediments dominate. Moreover, the high bedrock group velocities exhibit a typical wide-angle V-shape (depicted by a black line in all plots), in very good agreement with the bedrock-sediments boundary strike, which changes from WNW-ESE in the western part of the model to ENE-WSW in its eastern part (see fig. 1).

The group velocity maps determined from the surface-wave tomography procedure were used to reconstruct the local dispersion curves throughout the model area. The reconstructed dispersion curves were subsequently inverted using a node-based Monte Carlo 1D approach, with different model configurations in order to explore the derived model robustness. The final 3D model is in general agreement with previous results (Euroseistest 2D profile, borehole information, etc.) but also reveals new structural information for the study area, showing that the local geophysical/geological structure exhibits several 3D features (e.g. complicated fault geometry). The determined upper surface of the bedrock formation (transition from Vs=800m/s to typical bedrock velocities, e.g. Vs=1200-2000m/s) is presented in figure (3). In this figure, the dipping of the bedrock from the northern Mygdonia basin boundary towards the south is evident, with the overlying sediments obtaining a large total thickness of the order of 200-250m.

The results obtained in this work suggest that despite the complicated data patterns and processing, the application of full velocity modelling approaches using ambient noise tomography techniques at local scales (scales of several hundred meters to a few km) is a practically feasible target, though it cannot be easily applied as a black-box procedure. This work has been partly supported by

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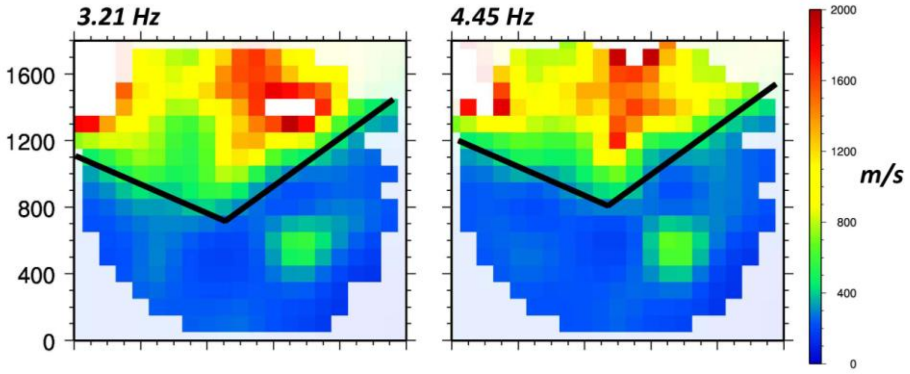

Figure 2. Group velocity maps for 2 sample frequencies, obtained for the study area (dashed line rectangle in Fig. 1). A characteristic wide-angle V-shaped pattern is identified for the transition boundary between high and low velocities, in agreement with the surface bedrock-sediments boundary strike seen in Fig. 1.

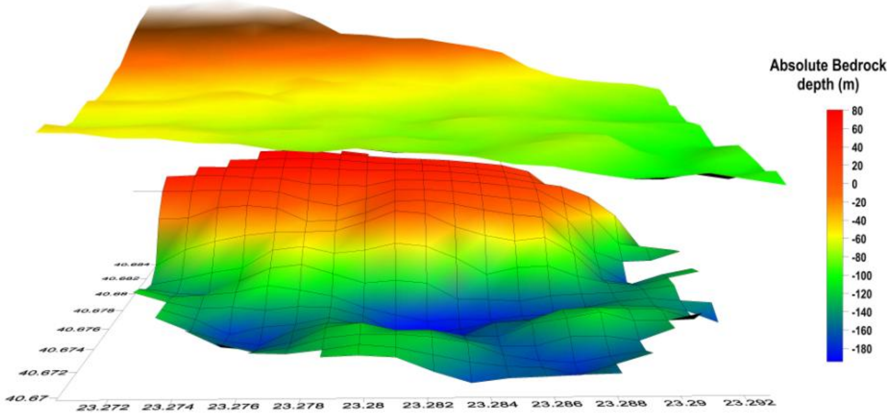

Figure 3. 3D morphology of the Mygdonia basin bedrock, within the study area. The surface morphology (shifted in order to facilitate the result presentation) is also shown.

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