

Determination of the subsurface structure of the Chora Plain (Samos) by seismic noise analysis

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Abstract

Seismic noise was passively recorded with mini-arrays, allowing shear wave velocities of individual layers to be estimated. A statistical analysis by beamforming was performed. A 1D underground model of the Chora plain was derived. Three dominant structures were found: coastal barrier, siltated lagoon and the interior of the Chora plain.

Keywords

archaeological prospection; forward modelling; landscape reconstruction; mini-arrays; passive seismic

Introduction

The area studied is located in the Chora Plain, a coastal depression in the southeast of the eastern Aegean island of Samos (Fig. 1a). Samos played a major role as a trading centre in ancient Greece. Since large parts of the island were not suitable as arable land, the fertile soil of the Chora Plain had great importance for the food and water supply of the Samian population.

In spring 2023, a drilling and direct push campaign will be carried out in cooperation between Kiel University and the German Archaeological Society for landscape reconstruction of the plain over the last 5000 years, to gain knowledge about the water and food supply of the Samian population, and for an estimate of the population size on Samos over time.

As preliminary work, passive seismic data were collected with mini-arrays in May 2022 to find suitable study sites. For this purpose, the sedimentary structure of the plain was to be roughly determined. The project is funded by the ROOTS Cluster of Excellence.

Methods

The methods commonly used in geophysical prospection, such as electromagnetic induction (EMI), ground penetrating radar (GPR) or electrical resistivity tomography (ERT),

have a penetration depth of only a few meters, which is too shallow for landscape reconstruction. Therefore, seismic was used as a measurement method for this task. For seismic depth sounding and estimation of shear wave velocities of individual layers, seismic noise was passively recorded on 84 mini-arrays along three profiles (Fig. 1b), and the dispersion of the Rayleigh wave was determined. The two-dimensional geophone arrangement shown in Figure 1c was used. The configuration is composed of an outer square (2.5 m x 2.5 m) and an inner square (0.7 m x 0.7 m), so it has a relatively small footprint.

A statistical array analysis is performed in the frequency range from 2 Hz to 80 Hz. The data of each mini-array is narrowband filtered and divided into short, overlapping time windows. For each time window a slowness value, the propagation direction (backazimuth) and a coherence value are determined by beamforming. To minimize statistical errors, the slowness values of the 20 data points with the highest coherence are averaged to obtain the dispersion velocity.

From this, dispersion curves for all arrays can be derived by plotting the phase velocity versus frequency. A dispersion spectrum can then be generated using the *qseisfk* algorithm (Wang 1999) based on a defined 1D background model. This model must be adjusted until the dispersion curve of the fundamental mode of the spectrum resembles

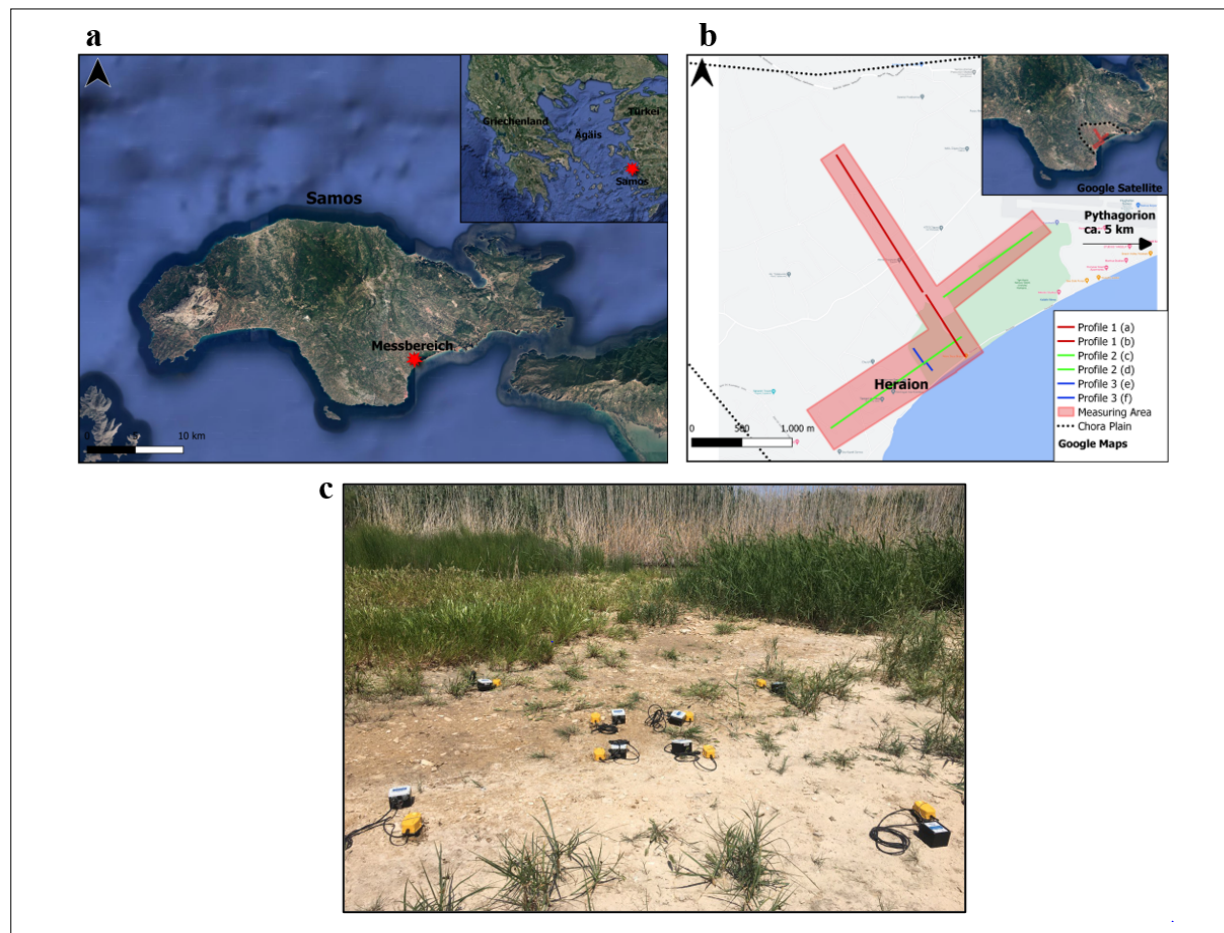


Fig. 1: a) Location of Samos and of the study area in the Chora Plain in the Southeast of Samos. b) Study area with the profiles. c) One mini-array with eight geophones as an example. We used the shown configuration for the measurements.

the previously calculated dispersion curve. Since there are ambiguities in the models, it is important to compare the models of neighbouring arrays and adjust them if necessary. From this, velocity distribution plots as a function of depth can be generated.

Results and discussion

Figure 2a shows an example of the subsurface model of profile 1 which runs vertically to the coastline. From 300 m to 600 m a depression can be seen in the boundary of the layers with 300 m/s and 500 m/s shear wave velocity, which extends to a maximum depth of 30 m. Relatively high velocities of 1000 m/s to 1200 m/s emerge from about 800 m inland at a depth of 20 m. Overall, high velocities dip from the west towards the east. Between 350 m and 750 m, a low-velocity region is visible at depths of about

3 m to 6 m with velocities below 100 m/s, vertically surrounded by velocities slightly above 200 m/s.

The lateral velocity distribution (Fig. 2b) shows a deep velocity region with shear wave velocities of below 100 m/s parallel to the shoreline. The velocity of this region contrasts sharply with the surrounding higher velocities, especially at depths of 4 m. From a depth of about 9 m, it is hardly discernible.

Figure 3a shows the petrophysical interpretation of the front part of profile 1. The shear wave velocities of the layers are assigned to different sediment and rock types (Hızlar et al. 2012).

The approximately 1.6 km long and 450 m wide area parallel to the coastline, with velocities below 100 m/s, which is particularly evident at a depth of 4 m, could be interpreted as part of an oversedimented lagoon. A lagoon is a shallow body of water separated from the sea by a landform, with sediments largely composed of clay, sand,

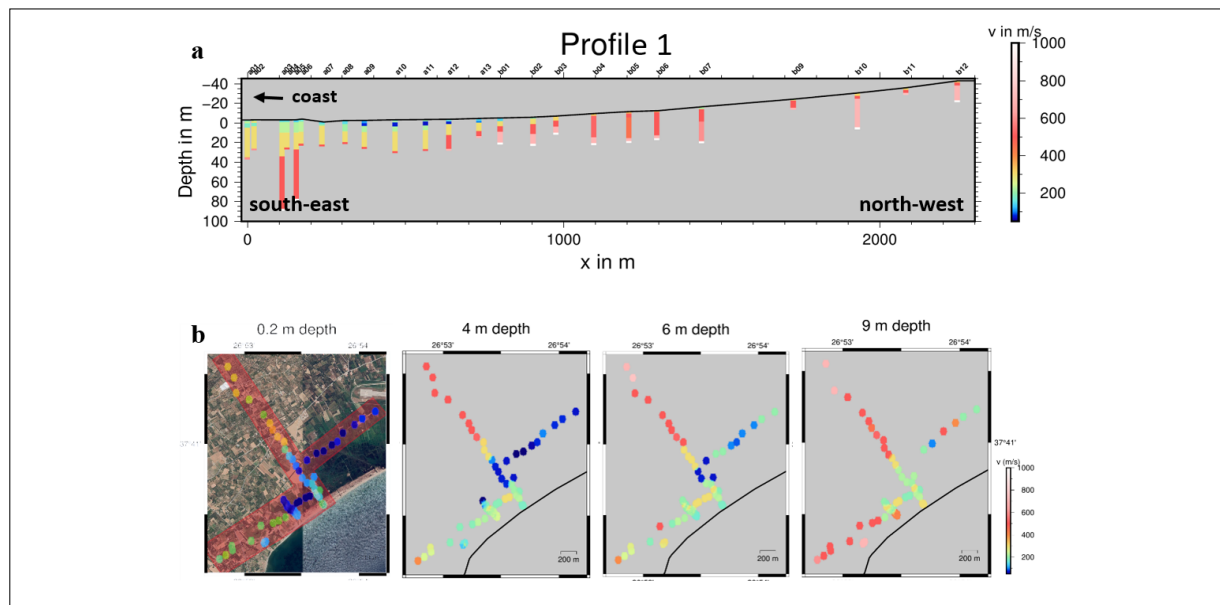


Fig. 2: a) Subsurface models of the 2300 m long profile 1. The black line represents the height of the earth's surface. b) Lateral velocity distribution plots according to 0.2 m, 4 m, 6 m, and 9 m depth. The black line represents the coastline.

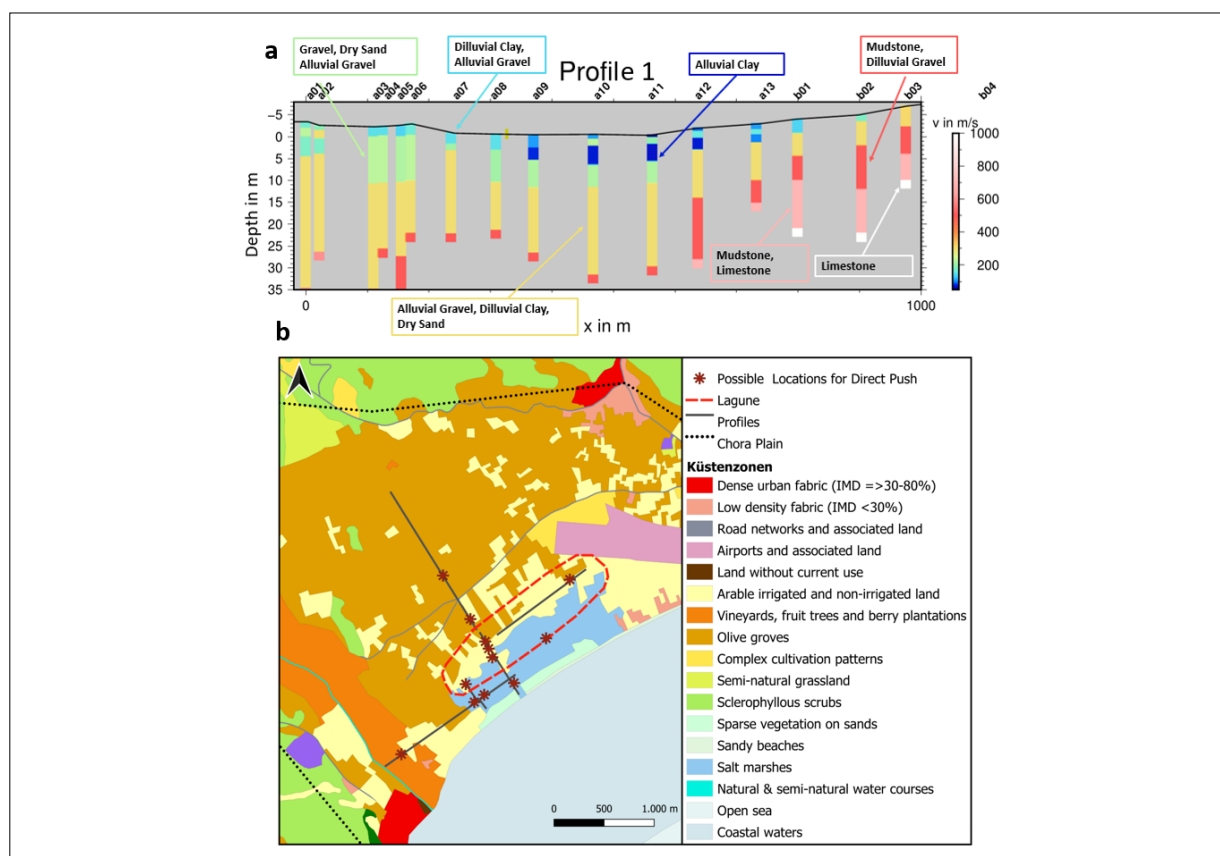



Fig. 3: a) Petrophysical interpretation of the results. Shear wave velocities of the front part of profile 1 assigned to different sediment and rock types (Hizlar et al. 2012). b) Coastal Zones map of Copernicus with possible locations of the Direct Push campaign in 2023. © European Union, Copernicus Land Monitoring Service 2018, European Environment Agency (EEA), Coastal Zones.

and biogenic material (Omogbe et al. 2020). This area is shown along with a coastal zone map of *Copernicus* (Fig. 3b). The map shows an area classified as a salt marsh (blue) which runs parallel to it with a slight offset to the southeast. Since salt marshes are often contained within lagoons, this would reinforce the assumption that lagoonal material may be involved.

Also shown on the map are possible locations for the drilling and direct push campaign in spring 2023. These were placed so that the course of the individual layers of the sedimentary basin can be traced and, in particular, so that the area interpreted as a lagoon/salt marsh can be studied in more detail.

Conclusion

The results of this work can be used as a basis for planning the 2023 Direct Push campaign. The array method is generally well suited for preliminary investigations in geophysical prospecting and gives the opportunity to obtain a rough overview of the subsurface structure with relatively little effort. Especially if, as in this case, it is known that the material is clayey and very soft, which strongly attenuates electromagnetic waves, passive seismic can be considered as a prospecting method. 

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