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Was the Piraeus peninsula (Greece) a rocky island? Detection of pre-Holocene rocky relief with borehole data and resistivity tomography analysis

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ABSTRACT

According to historical documents, Piraeus was a rocky island consisting of the steep hill of Munichia, known as modern-day Kastella. It was connected to the mainland by a low-lying stretch of land ("Halipedon") that would flood with sea water most of the year and was used as a salt field whenever it dried up. Apart from being an area of archaeological interest, the extended area of "Halipedon" is densely populated, thus being of geotechnical interest and is currently being investigated through borehole and geophysical data analysis. 52 boreholes were lithologically-geomorphologically analyzed and results from 11 resistivity tomography profiles were considered. Lithostratigraphy of the borehole data was classified into three lithostratigraphic units: Cultural deposits, Pleistocene–Holocene deposits, pre-Holocene bedrock ("Marls of Piraeus"). The deeper unit shows a big depression in the southeastern part of the survey area and a circular sinking (channel) in its north part. These depressions were probably covered by the sea at a time when the southern part of the Piraeus peninsula was an island. This is confirmed by stratigraphical and geophysical investigation in the area where resistivity tomography profiles could be performed. The big southeastern depression is covered by the river sediments implying a high sedimentation rate.

1. Introduction

In prehistoric times, Piraeus was a rocky island, as Strabo confirms (Jones, 1968) that consisted of the steep hill of Munichia, modern-day Kastella, and was connected to the mainland by a low-lying stretch of land that flooded with sea water most of the year and was used as a salt field whenever it dried up (Panagos, 1968; Garland, 1987). Consequently, it was called the Halipedon, meaning the 'salt field', and its muddy soil made it a tricky passage. Through the centuries, the area was increasingly silted and flooding ceased. Thus, by early classical times, the land passage was made safe. The rocky island of Piraeus was connected to the mainland during the 5th century B.C. (Strabo in Jones, 1960, Conwell, 1992), In ancient Greece, Piraeus assumed its importance with its three deep water harbors, the main port of Cantharus and the two smaller ports of Zea and Munichia (Loven et al., 2007) and gradually replaced the older and shallow Phaleron harbour which fell into disuse (Fig. 1). In the late 6th century BC, the area drew greater attention due to its advantages. In 511 BC, the hill of Munichia was fortified by Hippias and four years later, Piraeus became a deme of Attica by Cleisthenes.

Recent geoarchaeological research (Goiran et al., 2011) has suggested that Piraeus was an island, as previously mentioned. This research was based on samples taken by ten boreholes in the northern area of the Piraeus peninsula which were analyzed for microfaunal content and radiocarbon dating. Four maps show the paleogeographical evolution of Piraeus during Holocene.

Today, Pireaus is the main port of Greece (Fig. 2), the neighboring city of Athens and, like the capital, is densely populated, showing clear signs of rapid growth and change.

The detection of the landscape's evolution provides much information and data for geotechnical and paleogeographical studies that can help optimize urban planning in the further development of the city. It was within the context of this purpose that a borehole data analysis and geophysical study was

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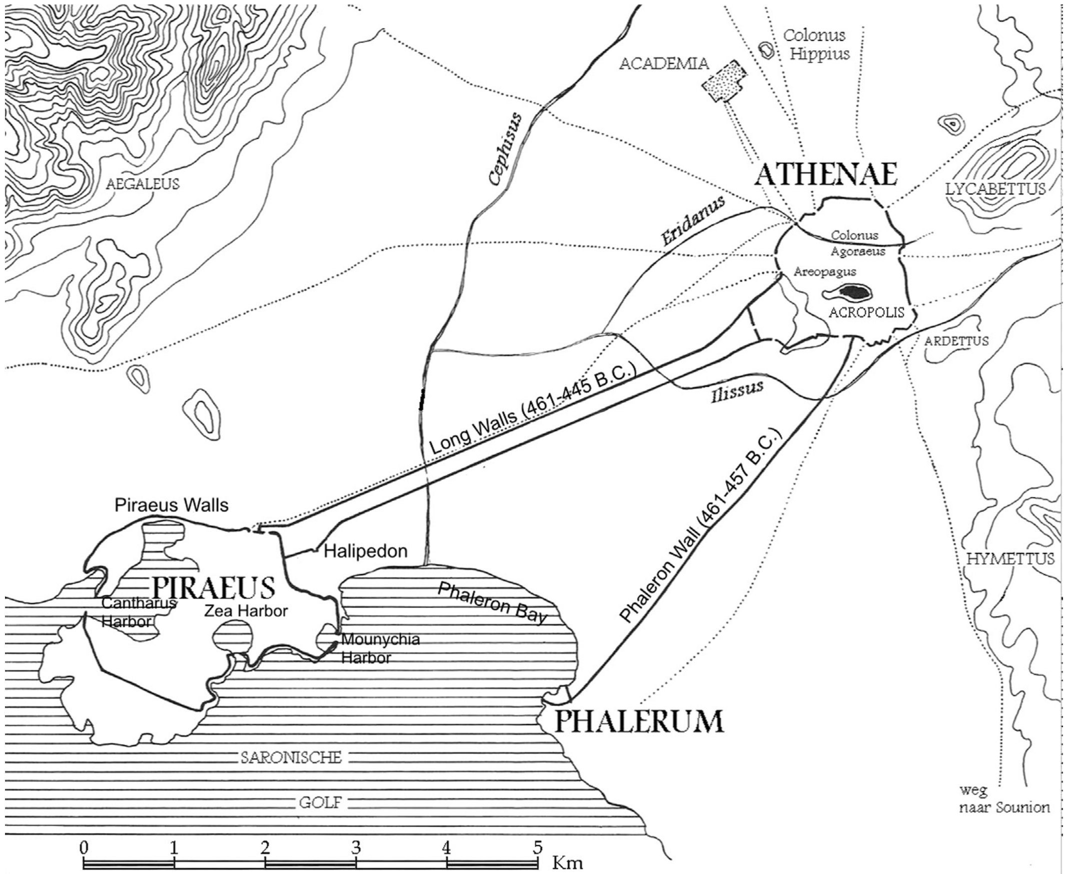

Fig. 1. Map of the south-west part of Attica, Greece, that shows a) the great walls connecting the city walls of Athens and Pireaus in ancient times, b) the three deep water harbors of Pireaus, the main port of Cantharus and the two smaller of Zea and Munichia.

conducted with the geophysicists and geomorphologists working in parallel. More specifically, data from 52 boreholes were analyzed for their lithostratigraphy and were correlated with resistivity data taken from 11 Electrical Resistivity Tomography (ERT) profiles (Fig. 3).

2. Geology of the Piraeus and Neo Faliron area

Papanikolaou et al. (2004) have presented a paleographic evolution of the Athens Basin from Upper Miocene to present. The Athens Basin represents a complex neotectonic asymmetric graben bounded by NNE–SSW marginal faults. The presence of sedimentary sequences indicates continental and lacustrine sediments in the west and north and coastal marine sediments in the southeast. An E–W fault zone divided the basin in a northern subsided part and a southern part where lakes existed only during Late Miocene in the central – western part, while shallow marine environments dominated in the south and southeast during Late Miocene–Pliocene with the coast line being very close to the present day Acropolis and Philopapou hills. The central eastern area was in a high position with the Alpine bedrocks under erosion and constituted a barrier towards the south. This situation changed before the middle Pleistocene when the Kifissos River was formed in such a way that it cut through the hilly area and connected the northern drainage system with the south, which resulted in the saturation of the remnant lakes of the northern segment.

The existing formations covering the greatest area in the site under survey are Pliocene and Pleistocene deposits, as well as the Holocene river deposits. In a small area, there are deposits of talus material, coastal deposits of sands and silty sands which were outlined in older geological maps (Lepsius, 1893) and are now covered by cultural deposits of the decades that followed.

On analyzing the geological status of the area (Fig. 4), it has been found that the geological formations from older to newer are:

- Upper Cretaceous limestones found in the broader mountainous area north of Piraeus Harbor.
- Marls, marly sandstones and limestones, conglomerate, collectively referred to as "Marls of Piraeus". There are also thin layers of siltstones, clays, silty and clayey sands. The formations and their thickness vary from place to place but the most dominant are marls and marly limestones in alternation with a relatively high percentage of calcium carbonate (more than 50%). The overlying loose sediments usually consist of alternations of clayey or sandy silts, silty sands and sands with shells and organic material. Thin layers of gravel and sand usually exist between marl and loose silty layers which in some places transform into loose conglomerate. From a geological point of view, "Marls of Piraeus" are Neogene sediments of a shallow marine environment, subdivided into two units. The upper unit is the result of continuous sedimentation in a low energy marine environment (Charalambakis, 1952), shown as semi-horizontal layering. The underlying lower unit is in tectonic unconformity with the upper unit and has the same composition and age. Marly sandstones and marls are characterized by differences in the process of sedimentation caused during certain periods by the predominance of more or less