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The Contribution of Simulated Lithostratigraphy in the Geoarchaeological Research of the Athenian Basin during the Holocene

Dimitrios Vandarakis, Kosmas Pavlopoulos, Costas Vouvalidis, Eric Fouache and Vasilios Kapsimalis

Introduction

The Athenian Basin has been inhabited since the Neolithic, but the most massive-scale human impact on the landscape has been recorded since 2,500 yBP, following the construction of the Long Walls and the Piraeus Harbors (Zea, Mounichia, Kantharos). This certainly contributed to Athens’ spectacular efflorescence in the 5th c. BC, but also created major morphological variations. These constructions have been described by ancient writers and valid observers such as Plato, Strabo, Pausanias and Plutarch. Strabo suggested that Piraeus might have been an island, based on its morphological smoothness and oral tradition.

The present study includes the larger part of the Athens basin. The study area begins from the coastal areas of Palaio and Neo Phaliro, goes up North to the Tourkovounia (East) and ends at Peristeri (West) (Fig. 1). This vast area corresponds to the Basin where the drainage networks of Kephissos and Ilissos, the two main rivers of Athens, have deposited their sediments. The objective of this research is to manage and to project the lithostratigraphic units identified in a GIS database with the contribution of Rockworks 15 and Arc Map v10.1 platforms. This task can be concluded by using borehole data, geo-archaeological data and

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1. Map of the study area.
finally extrapolate the landscape processes and the palaeo-geographic evolution of the study area during the Holocene (ca. 11,500 yBP until today), which is of most interest to archaeologists.

Methodology

Quantity and quality data were collected in order to obtain results as accurate as possible. Topographic-geological, bathymetric, historic-archaeological, and sedimentological data were collected, described, analyzed, combined, evaluated and interpreted in order to produce the paleogeographic maps of the study area.

Specifically, the topographic maps (Hellenic Military Geographical Service 1:5,000 in scale), the geological maps (Institute of Geology and Mineral Exploration, scaled 1:50,000) and the bathymetric data (Hellenic Center of Marine Research) were digitized in ARC MAP v. 10.1, in order to create the platform on which the sedimentological and the historical data would be computed. From the topographic data, a Digital Elevation Model (DEM) was created to represent the modern landscape. Information regarding the topography, the relief of the study area, and the relative sea level were extracted from the DEM.

In total, two hundred twenty-seven (227) boreholes were used for the study. Specifically, ten (10) sampling boreholes referred to the area of Piraeus and its suburbs. These boreholes were extensively studied, sampled and analyzed. More than forty (40) ^14C datings were derived from their sampling. Fourteen (14) geotechnical boreholes were documented from the environmental study of the New Cultural Center of Athens, funded by the Stavros Niarchos Foundation; and two hundred and three (203) geotechnical boreholes were collected from the National Center for Documentation (see Fig. 2 for the location of all 227 boreholes). These boreholes were described, studied, evaluated and displayed using the Rockworks 15 (National Technical University of Athens) Arc Map v.10.1 platforms. The stratigraphic units of the boreholes were separated in six (6) lithostratigraphic units, according to the sedimentological, granulometric, geoarchaeological and dating data from the collected samples, derived mainly from charcoals and shells.

Results

To create the lithostratigraphic units, the digitization of the printed data in stratigraphic columns was processed through the Rockworks 15 platform. The lithostratigraphic units were discriminated and separated. More precisely, in order to obtain appropriate information regarding the paleogeography of the Athenian Basin, the stratigraphic data were studied extensively, and separated in lithostratigraphic units according to 1) their consistency, 2) deposition environment and 3) chronology of deposition. Following the processing and the evaluation of the data, six lithostratigraphic units were defined (Unit A: Anthropogenic sediments, Units B1, B2: Holocene sediments, Unit C: Pleistocene sediments, Unit D: Neogene sediments, Unit E: Substratum of the Athenian Basin).

- Unit A consisted of anthropogenic sediments such as pebbles, cobbles, and archaeological remains, which are poorly sorted and very disturbed.
- Unit B1 is mainly made of very fine material such as clay, silt, and fine sand, deposited by marine processes. This unit can be detected in the coastal zone of the study area.
- Unit B2 consisted of sands, silts, clays and rounded pebbles, transported by fluvi-torrential processes.
- Unit C consisted of Pleistocene deposits with a brownish color, which are cohesive.
- Unit D is made of conglomerates with yellowish brown cementing material.
- Unit E represents the substratum of the Athenian Basin.

All units were then included in the GIS database. Subsequently, the lithostratigraphic columns of the boreholes were designed through the Rockworks 15 platform and used for the creation of the paleogeographic maps through the combination of the Arc Map v.10.2.1 and Rockworks 15 platforms.

In order to represent and describe the paleogeography of the study area, 4 profiles (Fig. 2) were produced, allowing us to analyze the lithostratigraphic sequences. Three profiles were designed with a W-E orientation (A-A’, B-B’, C-C’) and one with a SW-NE orientation (D-D’). The profiles (Fig. 3) show the spreading of the lithostratigraphic units in a W-E orientation delimiting the deposits of the Kephissos drainage network, indicating the progradation of the deposits. This sedimentation is dominated by the faulting zone of the Athenian Basin. The Quaternary tectonic movement has created an accommodation space for these deposits (Figs 2, 4).

For the representation of the lithostratigraphic profiles, 3D models were designed. They represent the thickness

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7 Marinos 1999.
2. The location of the boreholes, the profiles, the most important archaeological sites and the fault zone of the study area.
and the progradation of the lithostratigraphic units in the study area (Figs 3, 4). These images provide information regarding the paleo-landscape of the area in different periods of deposition during the Holocene (Fig. 4).

Also, the design of three 2D lithostratigraphic subsoil maps, showing the spread of each lithostratigraphic unit separately, is evident (Fig. 4). From the study of these images in combination with the profiles, relevant information can be extracted about the proliferation of the lithostratigraphic units (Figs 3, 4).

When observing the figures (Figs 3, 4), it appears that the sedimentation follows the specific relief which has dominated the Athenian Basin. This relief also creates the accommodation space for the deposits of the Kephissos drainage network, the fluvio-torrential sediments (Unit B2), and the anthropogenic sediments (Unit A), which has been deposited over Unit B2. Similarly the coastal-lagoonal sediments (Unit B1) have overlain Unit B2. From the study of the lithostratigraphic images and profiles, two depressions can be identified, the first in the central part of the Basin (Athens) and the second in the coastal area in the southern part of the Basin (Piraeus - P. Phaleron) (Fig. 2). In these areas the thickness of the deposits of all periods is very deep, showing a depression which was infilled with Holocene sediments (Units: A, B1, B2) (Fig. 4).

The maps were designed in order to represent the evolution of the sedimentation in the study area and show the thickness of the specific Unit (the thickness changes color every 5m). This depression also creates an extended lagoon in the coastal area from 8,000 yBP to 2,500 yBP.10 The infill of the lagoon started by separating it in two parts as shown in the subsoil map of Unit B2, approximately 8,000 to 4,500 yBP until today. The lagoon was then completely transformed, firstly in a swampy environment, and subsequently infilled with sediments due to human activity.

To demonstrate the evolution of this filling with sediments, a succession of 3D images of the archaeologically significant lithostratigraphic units had to be drawn together (Fig. 4). This figure demonstrates the filling of the area through different periods during the Holocene.

This filling began naturally, mainly by the depositional processes of the Kephissos drainage network. Subsequently, during the Holocene, the climatic conditions changed, and due to the Sea Level Rise, marine sediments were deposited in this area. This was followed by a warm period during the Holocene, recorded around 4,500-5,000 yBP,11 at a time when the precipitation and the deposition reach a maximum in the eastern Mediterranean.

Consequently, the deposition of the fluviotorrential sediments was more active than the deposition derived from marine processes between 8,000-4,500 yBP,12 showing an overcoming of the fluviotorrential processes over the marine processes.

3. The lithostratigraphic profiles A-A′, B-B′, C-C′, D-D′ of the Athenian basin. (Source: Vandarakis et al. 2016, modified by Vandarakis et al.)

10 Goiran et al. 2011.
11 Finné et al. 2011, 3164-3170.
12 Goiran et al. 2011.
Discussion-Conclusions

By comparing the 2D lithostratigraphic profiles and 3D lithostratigraphic images (Figs 3, 4), along with the references from ancient authors and the historical data, paleogeographic maps can be drawn in order to represent the paleogeography of the study area. Four paleogeographic maps were designed to represent the evolution of the paleogeography in different periods (Fig. 5). The significant differences were observed in the coastal area of the Athenian Basin, where there are more dynamic processes than in the rest of the basin.

Based on the dating of the samples gathered from the sampling boreholes and comparing the results with the information derived from the interpretation of the quantity and quality data, four paleogeographic periods can be distinguished.

The first period, around 8.000–4.500 yBP (ca. 6000–2500 BC), shows that the coastal area was dominated mainly by a large shallow lagoon protected from the marine processes, as shown in the fine-grained sediments (silt and clay) which define a low energy environment (Fig. 5A). This lagoon severed the “island” of Piraeus from continental Attica. The Ilissos River was probably joining Kephissos River, and these two rivers combined, were cast out into the sea.

Around 4.500 yBP (ca. 2500 BC) the lagoon started to be infilled with sediments from the drainage network of the area, and became separated into two parts (Fig. 5B). This can be explained by climatic change, a peak in precipitation in the eastern Mediterranean, and by the low rate of Sea Level Rise during the Holocene (RSL–Relative Sea Level approximately -2m below present sea level).18

13 Goiran et al. 2011.
14 Goiran et al. 2011.
17 Finné et al. 2011, 3164-3170.
5. All the paleogeographic maps according to different periods, A) 8,000 yBP, B) 4,500 yBP, C) 2,500 yBP, D) Recent landscape.
Subsequently, in 2,500 yBP (ca. 500 BC), these two lagoonal entities started to become increasingly swampy\(^{19}\) (Fig. 5c). This is indicated by increased evidence of anthropogenic activity in this area, which was motivated by the need to stabilize the constructions from subduction, the latter being provoked by the loose sediments and the swampy environment of the area.

Finally, the last map (Fig. 5d) shows the modern landscape of the study area after the interference of human activity. The coastal and central parts of the Athenian Basin have been extensively transformed into habitation areas for the Athenians. The drainage networks of the Kephissos and Ilissos rivers have been modified in order to cast out separately in the Phaleron coastal area. This interference not only transformed the natural environment but also dominated the natural processes, which shaped the current landscape. In the present study, we hope to have shown that the simulation of the lithostratigraphic Units in Geoarchaeology has contributed to the mapping of potential settlement areas and mooring places for various chronological periods. The simulation also delineated areas where archaeological research should be concentrated in the future.

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