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Holocene Palaeogeography of the Northern Margins of Giannitsa Plain in Relation to the Prehistoric Site of Archontiko (Macedonia – Greece)

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with 4 figures and 1 table

This article is dedicated to the memory of Professor A. Pilali – Papasteriou†

Summary. Archontiko is a prehistoric settlement, on a small hill on the northern margin of the Thessaloniki – Giannitsa plain. The present paper is an attempt to reconstruct the paleogeographic changes of the northern margins of this plain, close to the archaeological site due to the Holocene sea level rise. The Archontiko site is a very important archaeological site of the Thessaloniki Plain with continuous habitation from 2300 BC to the late Byzantine era. In this article, geomorphological and topographical surveys, along with three vibracores were undertaken. Sedimentological, palaeontological and stratigraphical techniques were applied to trace the marine, coastal and lacustrine palaeoenvironments in the northern shoreline of the Gulf of Thermaikos before the formation of the Thessaloniki – Giannitsa Plain. The deepest excavated archaeological strata of the Archontiko settlement dated back to 2300 BC and coincided with the existence of a lagoonal environment about 5 km away, indicating a restricted communication with the open sea. The end of the prehistoric settlement's occupation dates back to 1900 BC, an age which concurs well with the formation of a freshwater lake estimated at 2000 BC, with periods of marshy conditions especially in the lake coastal areas. The presence of the lake in the vicinity of Archontiko lasted until 200 – 37 BC. Finally fluvial processes and alluvial sedimentation shifted the lake southwards.

Zusammenfassung. *Paläogeografische Bedingungen im Holozän des Nördlichen Randes der Giannitsa Ebene, im Vergleich mit der prähistorischen Siedlung Archontiko (Mazedonien, Griechenland).* – Archontiko, eine prähistorische Siedlung, liegt auf einem Hügel am nördlichen Rand der Thessaloniki – Gianitsa Ebene. Ziel der vorliegenden Arbeit ist die Rekonstruktion der paläogeografischen Änderungen, die der nördliche Rand der Ebene aufgrund von Schwankungen des Meeresspiegels erlebt hat. Archontiko weist eine kontinuierliche Ansiedlung von 2300 v. Chr. bis in die späte Byzantinische Zeit auf. Daten wurden durch den Einsatz von geomorphologischen und topografischen Untersuchungen ermittelt, die durch Untersuchungen von Bodenproben aus drei Schlagkernbohrungen ergänzt wurden. Semimentologische, paläontologische und stratigrafische Methoden wurden verwendet, um die paläontologische Entwicklung von Meer, Küste und Lakustrinen entlang der Küstenlinie des Golfes von Thermaikos vor der Thessaloniki – Gianitsa Ebene zu verfolgen. Die tiefsten archäologischen Schichten weisen ein Alter auf, das bis ins Jahr 2300 v. Chr. zurückführt und mit der Existenz einer ca. 5 km entfernten Lagune übereinstimmt, was auf eine eingeschränkte Meeresverbindung hinweist.. Die prähistorische Besiedlung endet 1900 v. Chr. Ungefähr zur gleichen Zeit, 2000 v. Chr., entsteht ein Frischwasser-See, der Teile des Küsten-See-Gebietes in Sumpf verwandelte. Dieser See bestand in der Umgebung von Archontiko bis 200 – 37 v. Chr., bis ihn fluviale Prozesse und alluviale Ablagerungen nach Süden verschoben haben.

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1 *Introduction*

The plain of Thessaloniki – Giannitsa with the surrounding hilly landscape of the Axios Valley has been an area of intense occupation since antiquity. Neolithic settlements in the western part of the valley had been established 8 millennia ago (Rodden & Wardle 1996). Archontiko is one of the Prehistoric settlements of the area situated on a small hill along the northern margin of the Thessaloniki – Giannitsa Plain (Fig. 1). Its present position between the Ancient city (Classical & Roman) of Pella and the modern city of Giannitsa testifies to the importance of the area since prehistoric times. The significance of the Archontiko site is also documented by the continuous habitation of the site from 2300 BC till late Byzantine times. Thus far, the excavated stratigraphy of the Archontiko tell has revealed prehistorical strata with continual occupation dating back between 2300 – 1900/1600 BC, from the Early to the Middle Bronze Age (Pilali-Papasteriou & Papaefthimiou-Papanthimou 2002).

The present paper is an attempt to reconstruct the paleogeographical changes of the northern margins of Giannitsa Plain, close to the archaeological site because of the Holocene sea level rise. The recent landscape is the product of anthropogenic changes (Ghilardi et al. 2008), after extensive land reclamation during the 1930's (Albanakis et al. 1993). The natural landscape was an extensive freshwater marshy lake (Giannitsa Lake) (Fouache et al. 2008) which was formed when the progression of two deltas from opposite directions joined 30 km away from Archontiko, near the entrance of a former bay, isolating the inner portion from the sea.

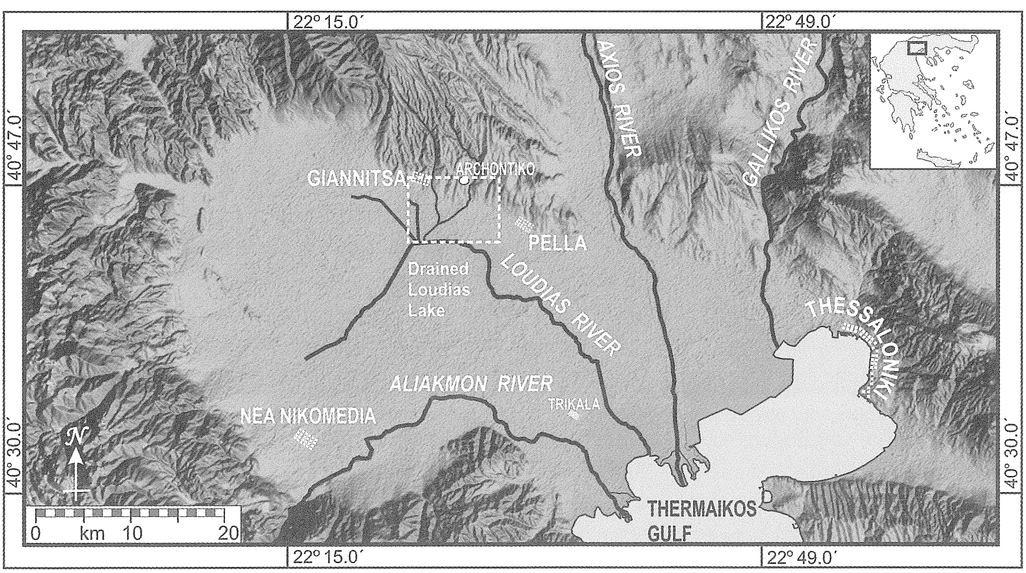

Fig. 1. The location of the Archontiko settlement and the area of interest in the northern margin of the Thessaloniki – Giannitsa Plain (relief from SRTM data, coastline and rivers from Landsat7ETM data).

1.1 *Regional Setting*

Thessaloniki's deltaic complex is the largest ($\sim$2000 km^2) deltaic area in Greece. It is situated in the northern part of the Gulf of Thermaikos (Fig. 1) which during the early Neogene was a tectonic depression formed by low angle normal faults with a NNW-SSE orientation (Dinter & Royden 1993). This tectonic depression of the Lower Axios Valley – Thessaloniki Plain – Gulf of Thermaikos gradually filled with clastic (conglomerates, sands, clays) and locally calcareous (limestones, marls) sediments. Sedimentation started during the Miocene period with fluvial sediments, continental red beds and brackish fossiliferous clays – sands – limestones; it continued during the Pliocene with fluviolacustrine sands, silts, lacustrine marly limestones; and finishes with Pleistocene continental red beds (Syrides 1990). The total sediment thickness is 3500 m at the centre of the basin (Faugeres & Robert 1976: 209). An intensive tectonic activity during the Middle – Upper Pleistocene, that also affects the Pleistocene red beds, reshapes the initial basin morphology (Syrides 1990).

During the Pleistocene era, the alternating palaeoclimatic conditions and the subsequent fluctuations of the sea level favoured terrestrial and fluvial clastic sedimentation and, locally, palaeosoil and redbed deposition. During last ("Wurmian") glaciation, the sea level fell at $\sim$120 m below the present level. As a result the shoreline and the Axios, Aliakmon, Gallikos river deltas shifted southwards; an extensive lowland almost flat section was formed in the area of the present-day Gulf of Thessaloniki – Thermaikos and the Thessaloniki Plain. This pre-Holocene terrain was mainly developed on Neogene sediments (northern margins) and covered by Pleistocene clastic sediments.

10,000 years ago the sea flooded the gulf forming a coastline at $\sim$30 m (Albanakis et al. 2005). This estimation has been based upon the bathymetry of the present gulf, the thickness of the Holocene marine sediments, and the sea level curve for the Gulf of Thessaloniki (Vouvalidis et al. 2005). The major rivers of the region (Aliakmon, Axios and Gallikos) started to create new deltaic formations in the area where the present deltaic plain is situated. The very large amounts of river sediment load and the shallow bottom topography led to the fast filling of the gulf and the rapid deltaic prolongation (Astaras & Sotiriadis 1988).

A marine bay extended, approximately 6000 years ago, up to the central part of the present alluvial plain of Thessaloniki (Ghilardi et al. 2008). This period corresponds to the maximum shoreline extension during the last post glacial sea level rise. Archaeological evidence showed that many Neolithic settlements were located close to the ancient shoreline. Data derived from the center of the plain (Ghilardi et al. 2008) showed that the area gradually changed from marine conditions to a large alluvial plain with gradual displacements of the shoreline to the southeast, caused by deltaic progradation. In the western part of the actual plain, an inland lake was formed and gradually shifted eastwards to Ancient Pella. The harbor of Ancient Pella was probably connected to this lake, before its siltation from the fluvial processes during the times of Alexander the Great and later.

Finally, in the first half of the 20th century a series of hydraulic works, extensive land reclamation and other human intervention took place and reformed the landscape by draining the old lake and canalising the rivers with manmade levees.

2 *Methodology*

Three (3) vibracores (P1, P2, P4), with a maximum recovery depth of 10 m below surface (Fig. 2), were drilled for the present study. Vibracoring equipment includes an Atlas Copco mechanical hammer (Cobra MK 1) and a cylindrical corer equipped with a 40 mm in diameter core cutter and basket type core catcher. The core sampler used (0.5 m in length for the cores P1, P2, and 1 m in length for P4) has an internal casing of 40 mm PVC tube, which was used as a container for the core sample. PVC tubes were sealed, marked and stored properly for further study.

All the samples were opened in the laboratory for analysis. After cutting the plastic tubes, the core samples were carefully split into two halves – a working half and an archive. Detailed photographic recording, with a digital camera, using an mm scale of every sediment core was realized, followed by stratigraphical and lithological descriptions. A Munshell Soil Color Chart was used for precise colour determination.

The determination of environmental facies was based on the analysis of fossil molluscs, and the lithology of the core samples.

The chronostratigraphy of the cores was determined by a series of six C^{14}-AMS radiocarbon determinations. Dated material includes 5 marine shells and 1 peat sample (Table 1). Four of the samples were submitted to Poznan Radiocarbon Laboratory in Poland, and the other two to CEDAD Laboratory (University of Lecce, Italy).

The topographical survey of the drilling sites and the field surveys in areas where the elevation data were not sufficient were done using of a Topcon FC100 differential GPS. The instrumentation accuracy was ≤ 1 cm in positioning and ≤ 2 cm in levelling. All the GPS measurements used the Greek grid and the mean sea level derived from Hellenic Military Geographical Service (H.M.G.S.) data.

Furthermore, interpretation of remote sensing data such as Landsat ETM7 and Quickbird (Digital Globe, Aug-02-2002 from GoogleEarth) were helpful tools in undertaking geomorphological analysis of the area as well as establishing the evolution of its landscape. For the 3D representation of the morphological relief, high resolution topographic data derived from S.R.T.M. (Shuttle Radar Topography Mission) surveys were used and superimposed on the satellite imagery in order to obtain the hypsometric information of the different landforms identified in the Giannitsa Plain. Previous works have highlighted a sound accuracy of this data in northern Greece (Andritsanos et al. 2004; Ghilardi 2006).

3 *Results*

3.1 *Geomorphology of the northern margins*

The interpretation of the Digital Elevation Model (DEM) derived from SRTM data for the area of interest in combination with the Landsat ETM7 and QuickBird images showed the depositional landforms shaping the morphology of the area studied. More specifically, the low flat area of the northern part of the Thessaloniki – Giannitsa Plain, in the vicinity of the Archontiko archaeological site, is situated between two alluvial fans (Fig. 2). These fans have been created by the fluvial action of the torrents originating from the hilly terrain of the plain margins. The morphological characteristics of the two fans are approximately the same, with the length and width

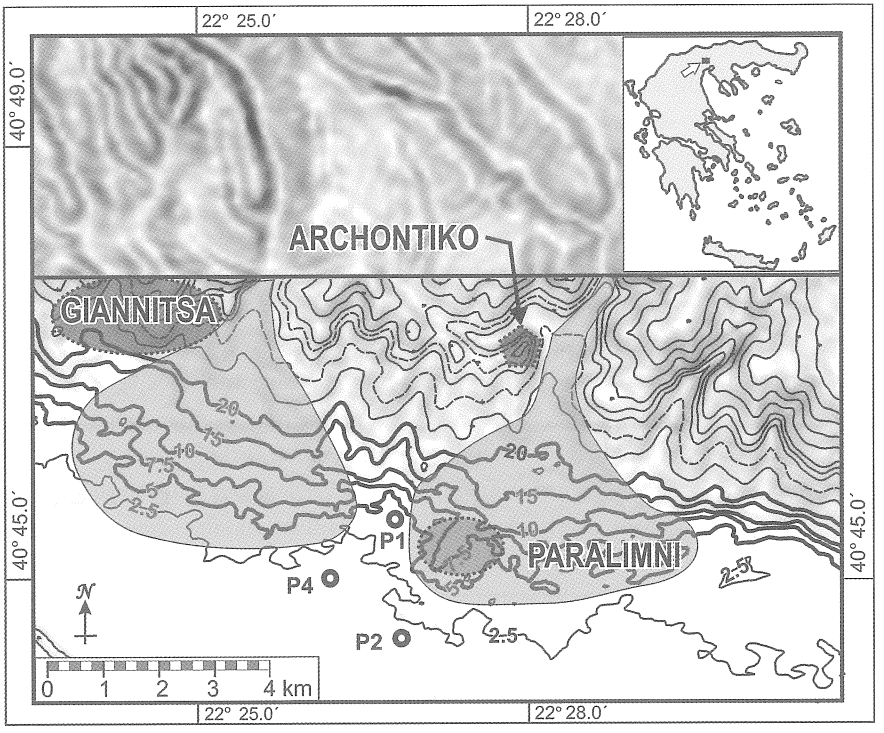

Fig. 2. Morphological map of the Archontiko Prehistoric settlement and the area of interest described with contours and Digital Elevation Model (in grayscale): alluvial fans (in gray), borehole locations (P1, P2, P4), and the modern villages.

of each at about 4 km, while elevation of the apexes is also nearly the same (~30 m). They consist of mainly coarse clastic sediments such as sand, gravel, pebbles intermixed with more fine sand, silt and clay, locally forming brownish loamy sediments.

The morphological characteristics of the alluvial fans verify the stratigraphical data derived from the vibracorings in the locations P1, P2 and P4 (Fig. 2). The P1 is located in the centre of a wide valley between the alluvial fans, but the presence of colluvial sediments above the pre-Holocene relief (Fig. 3) in the core samples confirmed the absence of fluvial fan depositional processes. Also the P2 and P4 drillings bordered the lower ends (feet) of the alluvial fans because they were located outside the depositional area of the fans (Fig. 2).

3.2 *Stratigraphy*

Three vibracore profiles named PARALIMNI 1,2,4 (P1, P2, P4) were retrieved from the area close to the village of Paralimni, on the northern margins of the Plain of Giannitsa (Fig. 2). Core sampling sites were carefully selected away from torrent fans, and focused on areas of low terrigenous influx.

Vibracore P1 (8.20 m deep) was drilled northwest of Paralimni village at +5.70 m a.s.l. between two small torrent fans (Fig. 2), in order to investigate the transition zone between the pre-Holocene basement (from the north) and Holocene sediments of Giannitsa Plain (from the south). Brownish to Brown reddish silty – sandy loams with scattered small gravel and a few pebbles were found through the whole length of this borehole, indicative of a terrigenous regime in this site (Fig. 3).

Vibracore P2 (10 m deep) was drilled south of the village of Paralimni at +1.63 m a.s.l. in the former bed of the reclaimed Giannitsa Lake. The aim was to penetrate the deepest part of the sedimentary fill. At the base of the profile (8.70 – 10 m) a terrestrial brown to reddish brown coarse sandy loam, with manganese spots and calcareous concretions was found (Fig. 3). Above this (5.40 – 8.70 m) marine sediments, dark gray-green silty clay with marine shells were discovered. This layer basewards is sandier with typical marine molluscs (*Nucula, Modiolus, Chlamys, Ostrea, Venus, Abra, Tellina, Corbula, Dentalium, Alvania, Bittium, Cerithium*), while upwards (5.70 – 5.90 m), where it is also sandier, mollusc fauna include *Cerastoderma glaucum* and *Bittium*, indicative of a lagoonal environment. The marine sediments are overlain by lacustrine sediments (5.40 – 2.50 m), well stratified gray-greenish laminated silt – fine sand, with a thin

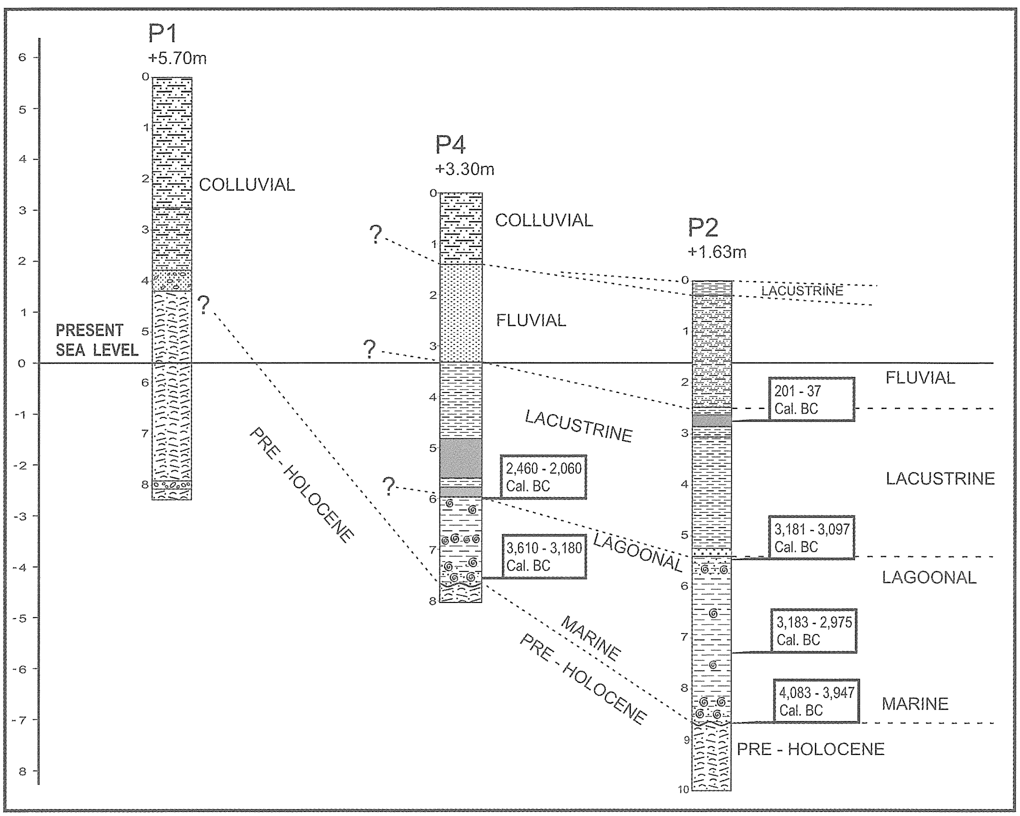

Fig. 3. Lithostratigraphy and correlation of boreholes.

brownish layer at the base (5.30 – 5.40 m) that contains many Charophytes; while in the upper part a peat layer at 2.60 – 2.80 m appears. Lacustrine sediments are overlain by Fluvial (deltaic) sediments (0.50 –2.60 m), dark olive green silts and fine micaceous sands with multicolour lamination. The top 0.50 m consists of blackish silty – clayey soil.

Vibracore P4 (8.00 m deep) was drilled west of Paralimni village at +3.30 m a.s.l. landwards of the former palaeoshore of the reclaimed Giannitsa Lake. Similar sediments with P2 were penetrated (Fig. 3). At the base (7.70 – 8.00 m) a terrestrial dark brownish sandy loam with calcareous concretions was found (Fig. 3). Above this (7.70 – 5.95 m) marine sediments, dark gray-green silty clay with marine shells were uncovered. The lower part (7.30 – 7.70 m) is sandier with typical marine molluscs (*Nucula, Modiolus, Chlamys, Ostrea, Venus, Abra, Tellina, Corbula, Dentalium, Alvania, Bittium, Cerithium, Murex, Cyclope*), while upwards molluscs (*Cerastoderma glaucum, Abra)* indicative of a lagoonal environment emerge. Marine sediments are overlain by lacustrine (3.30 – 5.95 m) sediments; at the lower part (~5.00 – 5.95 m), blackish peaty silts – clays and peat were found, while upwards (~5.00 – 3.30 m) laminated gray-greenish clay becomes visible. Above the lacustrine fluvial (deltaic) sediments (1.20 – 3.30 m) gray, gray-green laminated fine sands with mica scales and few plant remnants at the lower part were unearthed, while upwards these shift to massive olive gray sands with small scattered sandstone concretions. At the top of the profile (0.00 – 1.20 m) brownish sandy loam appears.

3.3 *Radiocarbon Dating*

The C^{14} method with the AMS technique was used to date five marine shell and one peat samples (Table 1). Three marine samples and one peat sample originate from borehole P2, while the other two marine samples from borehole P4 (Table 1). The four samples from borehole P2 were submitted to Poznan Radiocarbon Laboratory in Poland, and the other two from borehole P4 to CEDAD Laboratory (University of Lecce, Italy) (Table 1).

The conventional radiocarbon ages of the marshy sediment samples have been converted into calendar years by using the software OxCal Ver. 4.0 (Bronk-Ramsey 2007) based on the last atmospheric dataset (Reimer et al. 2004). For the mollusc shell samples, the conventional radiocarbon age was converted to calendar years by using the MARINE04 internationally accepted calibration curve for marine data (Hughen et al. 2004), and a local marine reservoir correction factor (ΔR) of 154 ± 52 as average value for the Aegean Sea.

The corrected ages are in normal vertical succession (no chronological incoherence was observed) with the overlaying samples being younger than the underlying ones. Samples P2 -7.35 m, and P2 -5.70 m reveal similar ages despite originating from different depths of the same borehole. Both of them include fragments of *Cerastoderma glaucum*, and euryhaline mollusc, from shallow lagoonal environments. Since both samples are not articulated but separated valves, it could be possible that a bioturbation process may have affected the vertical position of the samples.

Table 1. Radiocarbon ages for dated samples from the cores of the Northern part of the Thessaloniki-Giannitsa Plain close to the Archontiko Settlement, calibrated after INTCAL 04 (Reimer et al. 2004) and Marine04 (Hughen et al. 2004).

Sample code / Lab. Number	Depth below m.s.l. (m)	Material	$\delta^{13}C$ (‰)	Conventional R/C age (yrs BP) ($^{13}C/)^{12}C$ corr.)	2 σ calibrated age
P2-2.75m Poz-16763	1.12	*Plant Remnants (Peat)*	-28.1	2090±35	Cal BC 201 – 37 (2151 – 1987 Cal. BP)
P2-5.60m Poz-14366	4.07	*C. glaucum*	-9.7	4985±35	Cal BC 3281 – 3097 (5231 – 5047 Cal. BP)
P2-7.35m Poz-14368	5.72	*C. glaucum*	0.1	4920±35	Cal BC 3183 – 2975 (5133 – 4925 Cal. BP)
P2-8.65m Poz-16092	7.02	*Modiolus*	3	5730±35	Cal BC 4083 – 3945 (6033 – 5895 Cal. BP)
P4-6.00m LTL3682A	2.70	*C. glaucum*	-3.6 ± 0.1	4301 ± 40	Cal BC 2460 – 2060 (4410 – 4010 Cal. BP)
P4-7.50m LTL3684A	4.20	*Marine shell fragments*	+ 5.5 ± 0.2	5151 ± 50	Cal BC 3610 – 3180 (5560 – 5130 Cal. BP)

3.4 *Palaeoenvironmental Changes*

Different Palaeoenvironmental conditions were established during the Holocene era into the studied area as indicated by the different depositional facies. Four depositional sedimentary facies (marine, lagoonal, lacustrine and fluvial) were distinguished in the area studied. Similar facies were also recognized in the central part of the Thessaloniki Plain (Ghilardi et al. 2007), indicating lateral environmental continuation. Evaluation of the carbon dating results in combination with the sedimentological characteristics, and the synthesis of the mollusc faunas allow a time definition for the various palaeoenvironments occupying the area. The different palaeoenvironments can be synthesized according to the scenario which follows.

During the last glacial maxima, the area under study was part of an extensive plain. A very low hilly terrain dominated the terrestrial environment while the Holocene sea level rise affected the region. The sea transgressed this region and gradually reached the hilly terrain. The radiocarbon ages from the base of the marine sediments in boreholes P2 and P4 indicate that the sea first reached in P2 at ~4000 BC and later (~3500 BC) in P4, where the altitude of pre-Holocene palaeorelief was ~3 m higher. A shallow marine bay was formed, with normal salinity as indicated by the typical marine mollusc fauna (*Nucula, Modiolus, Chlamys, Ostrea, Venus, Abra, Tellina, Corbula, Dentalium, Alvania, Bittium, Cerithium, Murex*) included in these sediments.

The shallow bay gradually turned into a lagoonal environment in ~2500 BC with fine grained sedimentation and a monotonous brackish euryhaline mollusc fauna (*Cerastoderma glaucum, Abra, Bittium*). The end of the lagoonal and the beginning of a lacustrine environment is well documented in both boreholes P2, P4, where just above the marine sediments, a direct contact and further lacustrine sediments deposited above are seen. The radiocarbon age of P4 – 6.00 m allows an estimation of ~2000 BC for the beginning of the lacustrine environment. The presence of Charophyte oogonia in the first lacustrine sediments in P2 indicate clear water conditions, while in P4 the peat layer designates the existence of a marshy (coastal?) area in the lake.

Lacustrine sedimentation continues with fine grained laminated silts, clays, and very fine sands, the upper beds are characterized by a peat layer dated in ~100 BC (201 – 237 BC). The lacustrine environment is transformed (estimated at ~0 AD/BC) into fluvial (deltaic) and multi-coloured laminated micaceous sands were deposited indicating an increase in clastic influx into the area. The area was gradually transformed into an extensive shallow lake – marsh swamp with a fluctuating water level that dominated the area. The last relics of this environment vanished during 1930's reclamations. At P2 the uppermost marshy soil is the last remnant of what once was Giannitsa Lake.

4 *Conclusions*

The reconstruction of the palaeographical evolution of the Thessaloniki – Giannitsa Plain's northern margins was based on the stratigraphical, palaeontological and chronological analysis of the three corings situated in the area south of the prehistoric settlement of Archontiko. In addition, the palaeoenvironmental changes during the upper Holocene period as well as the archaeological data from the settlement were used to define the possible influence of the palaeogeographical changes on human habitation.

More specifically, regarding the region of the lower hilly terrain adjacent to the flat alluvial plain, between ancient Pella and Giannitsa town, we can conclude the following:

I. Due to Holocene transgression, the sea flooded the wider area of the Thessaloniki – Giannitsa Plain and created a shallow-bottomed marine gulf. Around ~4000 BC the sea reached the hilly terrain (Fig. 4a) and created a shoreline 5.5 km away from Archontiko Hill. Gradual sea level rise during the next 600 – 800 years shifted the coastline ~0.5 km further landwards shortening the distance between the hill and the sea (Fig. 4b).

II. Around ~3200 BC, maximum sea extension took place in the area as a result of the last postglacial sea level rise. The shoreline reached the location of the P2 borehole, at 4.9 km from Archontiko.

III. Subsequently, a gradual transition from marine to lagoonal palaeoenvironmental conditions (normal salinity to brackish conditions) is observed between ~3000 BC and 2500 BC. The rapid growth of the Axios and Aliakmon deltas created some levees, which gradually transformed into natural dams creating brackish environments around the bay (Ghilardi 2007). The water level continued to rise and the coastline shifted closer to Archontiko (Fig. 5c).

IV. A rapid palaeoenvironmental change took place around ~2000 BC and a freshwater lake formed in the area. Due to the continued rise of the lake's water level, the lake expanded and flooded the area as a result. At this stage, the lake shoreline was at the minimum distance from the Archontiko settlement (~3.8 km) (Fig. 5d).

V. Finally after ~0 AD/BC rapid alluviation and clastic deposition along the northern margins gradually moved the lake southwards (Fig. 5e). The fluvial processes prevailed in the vicinity and alluvial fan deposition changed the morphology of the earlier shoreline.

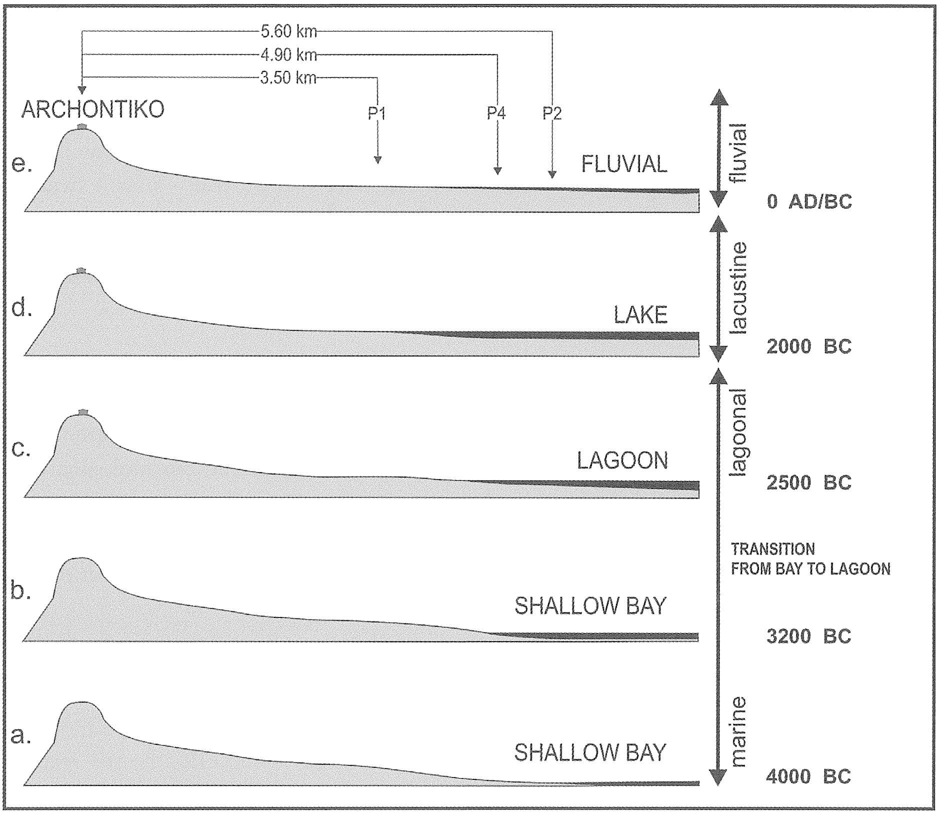

Fig. 4. Proposed palaeogeographical evolution of the northern margins of the Thessaloniki – Giannitsa Plain and the distance of the Archontiko Prehistoric settlement from the coastline.

Archaeological data (of the anthropogenic strata excavated thus far) indicate occupation of the prehistoric settlement between 2300 BC and 1900 BC. At that time (2300 BC) extensive coastal lagoons were situated ~5 km to the south. The sea was situated further southwards and shallow channels connected the lagoons with the open sea.

The end of the prehistoric settlement's occupation dates back to 1900 BC (no younger archaeological strata were found on the Archontiko tell). This age coincides well with the formation in the area of a freshwater lake estimated at 2000 BC. By that era, the sea lay several km southwards (Ghilardi 2007) and there was no connection to the lake. As the excavation on the tell of Archontiko did not yet reach the deeper (and older) archaeological stratigraphy, it could also be possible that initial occupation was older and probably favored by a pre-existing marine palaeoenvironment.

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