

PLATIA MAGOULA ZARKOU
THE NEOLITHIC PERIOD

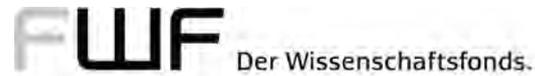
ENVIRONMENT, STRATIGRAPHY AND ARCHITECTURE,
CHRONOLOGY, TOOLS, FIGURINES AND ORNAMENTS

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Accepted by the Publication Committee of the Division of Humanities
and the Social Sciences of the Austrian Academy of Sciences:

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Printed with the support of the Austrian Science Fund (FWF) PUB 920-Z



and the Holzhausen-Legat of the Austrian Academy of Sciences.

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This publication was subject to international and anonymous peer review.

Peer review is an essential part of the Austrian Academy of Sciences Press evaluation process. Before any book can
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Austrian Academy of Sciences Publication Committee.

The paper used in this publication is DIN EN ISO 9706 certified
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English language editing: Nicola Wood
Graphics and layout: Andrea Pancheri
Coverdesign: Mario Börner, Angela Schwab

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ISBN: 978-3-7001-9036-3
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Printing: Prime Rate, Budapest

<https://epub.oeaw.ac.at/9036-3>

<https://verlag.oeaw.ac.at>

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II. The Environment and its Evolution around the Tell

II.1. The Latest Quaternary Evolution of the Peneiada Valley, Central Greece, and its Effects on Neolithic and Historical Settlement Distribution

Riccardo Caputo – Bruno Helly – Dimitra Rapti – Sotiris Valkaniotis

II.1.1. Introduction

The major questions posed at the beginning of the present research which we attempted to answer were the following: firstly, explaining the Late Quaternary evolution of the Peneios River, especially along the reach interposed between the Karditsa and Larissa plains. In this regard, a major target was unravelling the crucial role played by the Peneiada Valley in the framework of the central Greece hydrographic network, and hence understanding the important geographic and environmental changes that occurred within the broader area up to historical times.

Second was the tentative reconstruction of the latest Pleistocene–Holocene palaeogeographic and palaeomorphological setting of the area, where several Neolithic communities were established including, above all, the PMZ settlement, the major and best-known archaeological site of its kind.³⁰

In order to shed some light on the above issues, we investigated a much broader area, as the evolution of the PMZ site certainly depends on larger-scale natural phenomena mainly governed by the regional hydrographic network in all its aspects, for example the number, the dimension and the stability of the water courses; their water discharge and its seasonal variability; the occurrence and frequency of flooding events; and the extent of their effects on the surrounding plains, etc.

Geological and Hydrographic Framework

The present-day orographic texture of Thessaly and its broader surroundings is basically oriented NW-SE, which is the result, firstly, of the compressional phases building the Hellenides fold-and-thrust belt during the Oligocene–Miocene and, subsequently, of the Pliocene–Early Pleistocene tectonic inversion associated with a NE-SW crustal extension.³¹ The overall result was a basin-and-range-like morphology alternating tectonic-topographic ‘highs’ (the Pindos Range, the Central Hills and the Olympos-Ossa-Pilion Range) and ‘lows’ (the Karditsa, Larissa and Thermaikos Basins).³² However, since the Middle Pleistocene, the geodynamics of the Aegean region have changed abruptly, being characterised by a c. north-south-stretching direction and the formation of new, roughly east-west-trending structures, like the Tyrnavos Basin and Gonnoi Horst³³ or the Almyros and Vasilika Basins,³⁴ in northern and southern Thessaly, respectively. Most of these normal faults are still in an incipient stage,³⁵ and hence the cumulative displacements are relatively

³⁰ Gallis 1989; van Andel et al. 1995.

³¹ Caputo 1990; Valkaniotis 2005.

³² Caputo – Pavlides 1993.

³³ Caputo et al. 1994.

³⁴ Caputo 1990.

³⁵ Caputo 1995.

small. In any case, the cumulated crustal deformation has not yet been sufficient to have radically changed the inherited regional-scale morphology.

The present-day hydrographic network of the Peneios River, the longest in Greece (Fig. II.1.1a), is strongly influenced by these pre-existing and still dominating morphologies (i.e. the NW-SE-trending basins). This is particularly evident in the low-gradient sectors of the water courses crossing these areas, that is to say, downstream the exit of the mountain valleys (generally between 150 and 120m asl) of the numerous channels entrenching the Pindos Range, the Antichasia Mountains and the Othrys area (Fig. II.1.1). It is worth noting that along the path of the Peneios River we were able to distinguish two major reaches draining wide and flat alluvial areas. The western one is represented by the Karditsa Plain and it is characterised by numerous affluents, mainly on the right side of the main stream, the last of which is the Enipeas River, probably the most important for its water discharge contribution (Fig. II.1.1a).

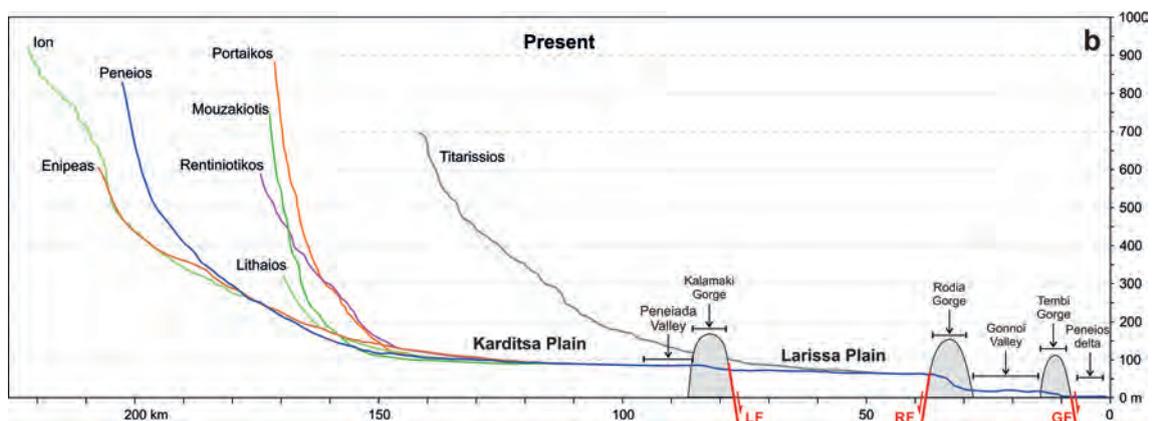
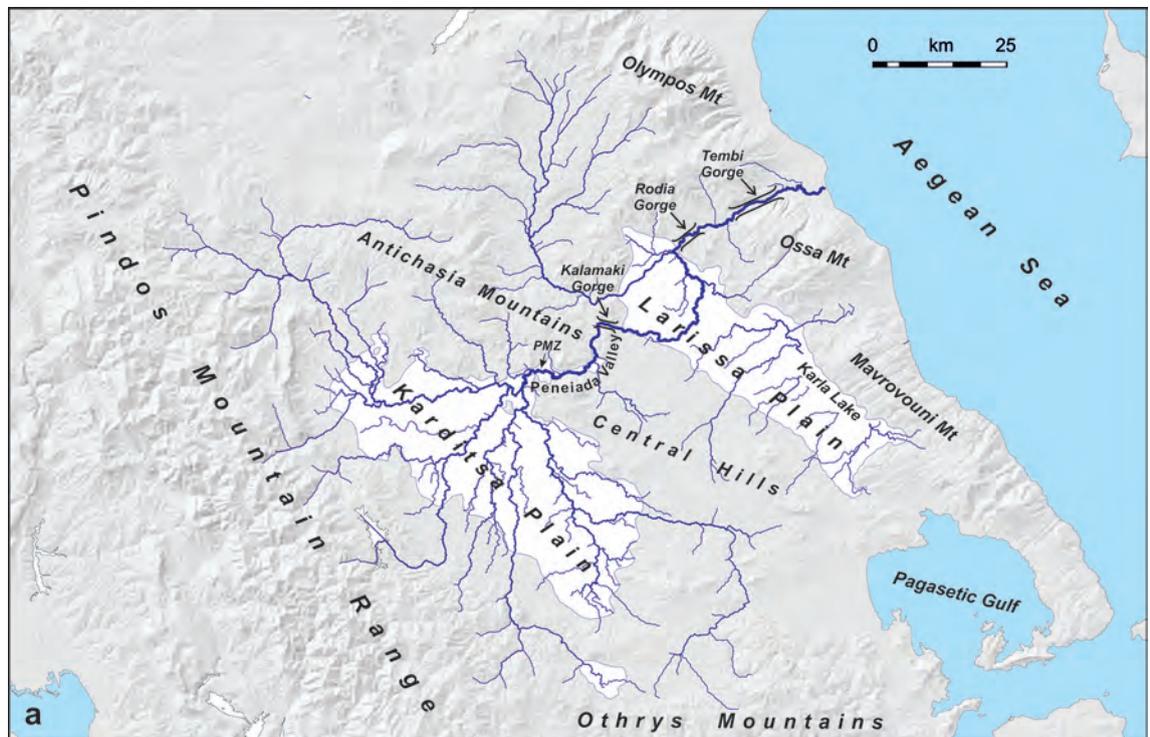


Fig. II.1.1 a. Hydrographic network of the Peneios River draining a large sector of central Greece. Note the morphological anomaly of the Peneiada Valley, investigated in the present research, separating the western Karditsa Plain from the eastern Larissa Plain; b. Present-day longitudinal profiles of the major rivers draining western Thessaly (R. Caputo)

The other major reach of the Peneios River, characterised by very low gradient flows across a flat alluvial area, is represented by the northern Larissa Plain, between the gorges of Kalamaki and Rodia (Fig. II.1.1a and b). In this case, however, the hydrography shows an anomaly because the river firstly flows ESE as far as the town of Larissa, where it abruptly turns northwards and then northwestwards before entering the Rodia Gorge. In this sector of the plain, a complex hydrographic evolution has been documented for the Holocene, with likely repeated natural attempts at deviation along the Asmaki channel towards the southeastern sector of the Larissa Plain.³⁶ This was due to a concomitant, though competing, role played by the major normal faults bordering the Tyrnavos Basin, the progressive sedimentary infilling and the hydrographic dynamics. Only anthropogenic activities carried out at the beginning of the 20th century impeded the definitive diversion of the Peneios waters into Lake Karla, and the consequent entrapment there due to the lower altitude of the southeastern Larissa Plain. Lake Karla was artificially drained during the 1960s and partially restored in recent years for environmental reasons.

Interposed between the two reaches that cross the wide Karditsa and Larissa plains, respectively, the Peneios River flows along a narrow alluvial plain, ranging from 0.5 to 3km in width, bordered by rocky mountain slopes. We refer to this morphological feature as the Peneiada Valley (from the small village on the left bank of the river; Fig. II.1.1a). This intermountain reach of the Peneios River is almost 30km long and the average slope of the alluvial plain is extremely low, corresponding to c. 0.5m/km (0.5‰; Fig. II.1.1b). The Peneiada Valley is characterised by numerous meanders, either active or abandoned ones (Fig. II.1.2).³⁷ Accordingly, the gradient of the water course is even lower, corresponding to an average of 0.3m/km (0.3‰). Based on the analysis of detailed topographic maps, cadastral maps and aerial imagery of different epochs, several overlapping meandering stages could be clearly recognised along the Peneiada Valley (Fig. II.1.2).

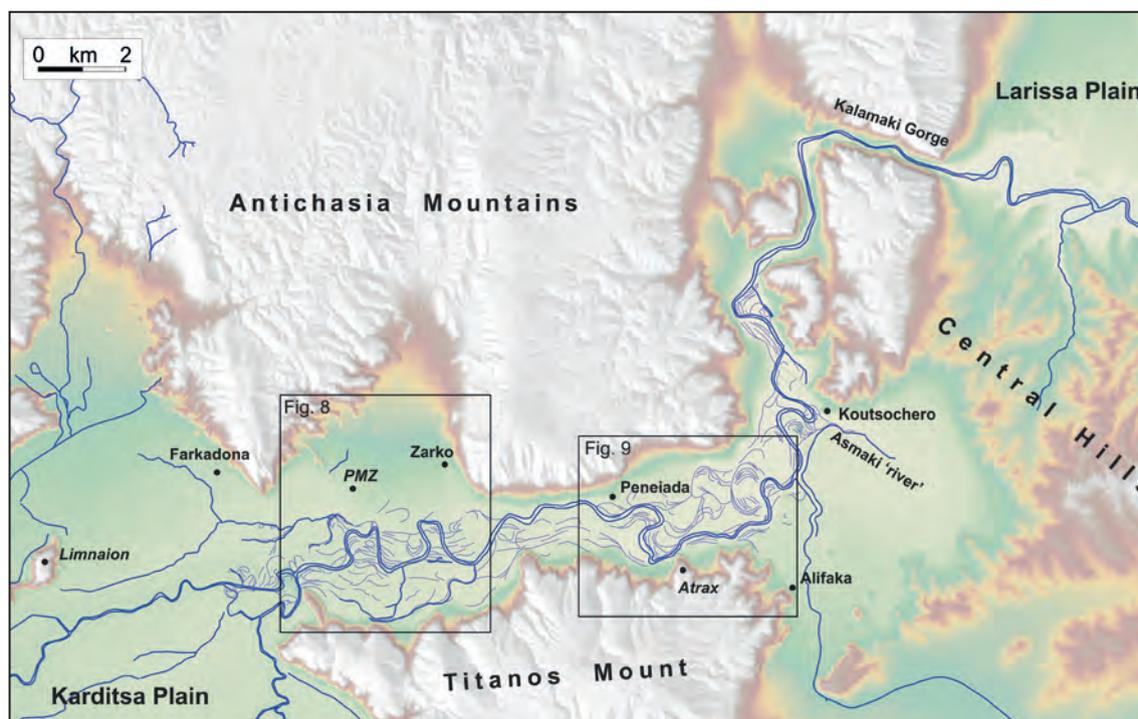


Fig. II.1.2 DEM of the Peneiada Valley showing the present-day Peneios River and the numerous meanders abandoned in historical times according to historical topographic maps (Heuzey – Daumet 1856; Nobile 1910; HAGS 1917). Boxes indicate the location of Figs. II.1.8, II.1.9 (R. Caputo)

³⁶ Caputo et al. 1994.

³⁷ Migiros et al. 2011.

II.1.2. Late Quaternary Peneiada Valley Evolution

Valley Bottom Geometry and its Infilling

A careful morphological analysis of the broader Peneiada Valley (Fig. II.1.2) suggests the presence of a marked hydrographic anomaly. In particular, following the present-day downstream path, the two valley flanks, consisting of rocky slopes and associated ejection cones descending the minor lateral valleys, get closer and closer. Indeed, the interposed alluvial plain is characterised by a progressive downstream narrowing, while the commonly inundated area during the periodical flooding events eventually disappears a few kilometres north of Kout-

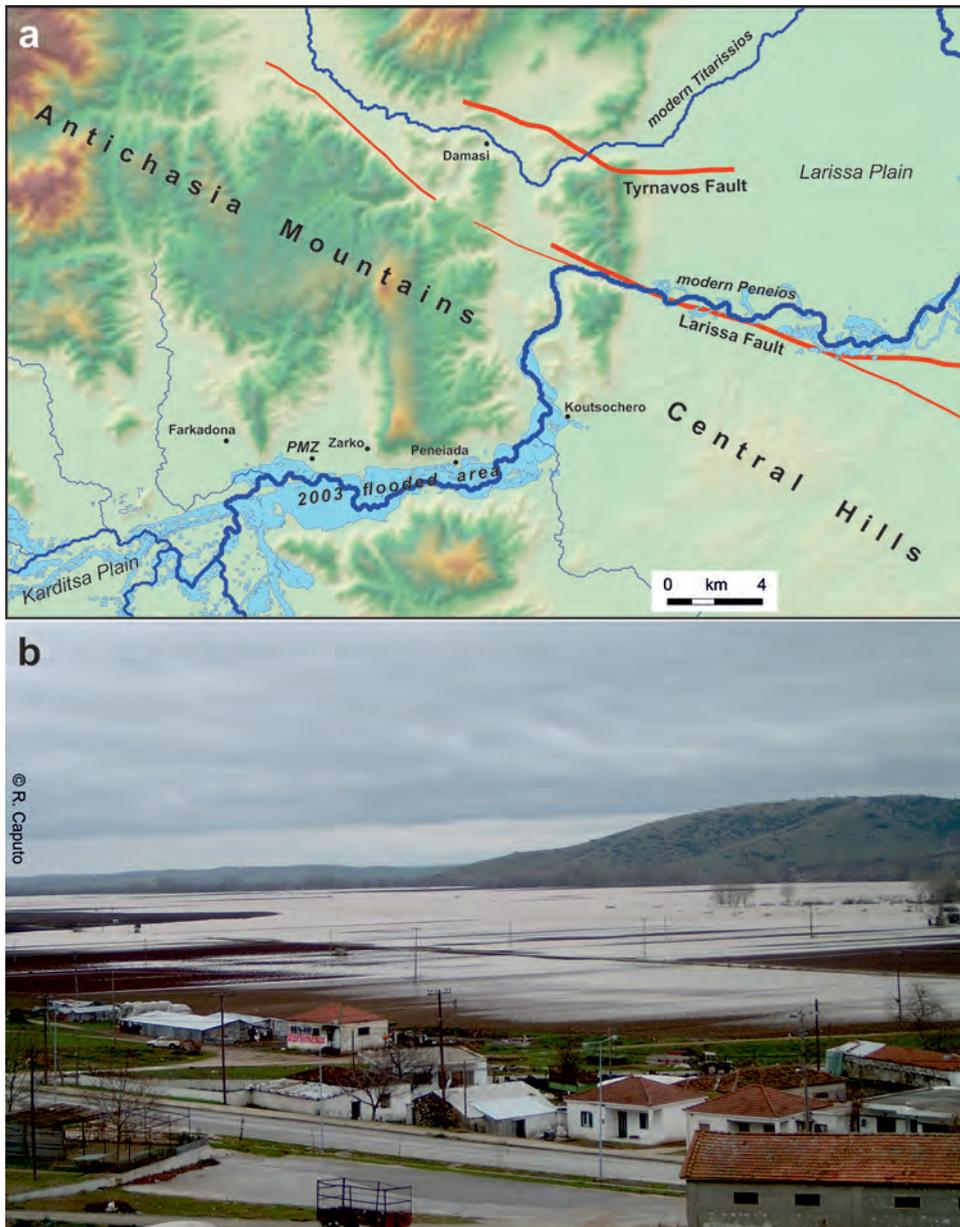


Fig. II.1.3 a. Extent of the flooded Peneiada Valley during the February 2003 event clearly showing that a large part of the alluvial plain is completely inundated up to few kilometres from the Kalamaki Gorge, where, instead, an entrenching process by the Peneios River dominates. In contrast, the upstream plain is continuously and repeatedly affected by fluvial deposition (viz. aggradation); b. Presence of the several metre-high water table that temporarily transformed the valley into a lake. Similar flooding events occur almost every year (R. Caputo)

sochero village (Fig. II.1.3). As a matter of fact, beyond this point, the Peneios River visibly entrenches its own bed, firstly affecting older fluvial deposits, then, the cemented lateral cones and, once in the Kalamaki Gorge, the Triassic bedrock itself. In summary, the morphological anomaly suggests a relatively recent and obviously still unbalanced natural process of path inversion of the water flow along a major reach (i.e. the Peneiada Valley).

Beyond the morphological evidence suggesting the inversion of the hydraulic (and topographic) gradient, a recent geophysical survey has reconstructed in detail the geometry of the basement underlying the recent fluvio-lacustrine deposits.³⁸ Although the absolute altimetric values of the reconstructed valley bottom have some minor uncertainties due to the simplified subsoil velocity model considered, the overall geometry of the palaeo-valley is well constrained and undoubtedly shows a regular south-and-westwards topographic gradient as represented in Fig. II.1.4. In other words, and neglecting any possible significant role of regional tilting by large-scale tectonic processes, any major water course flowing along the palaeo-Peneiada Valley was necessarily moving

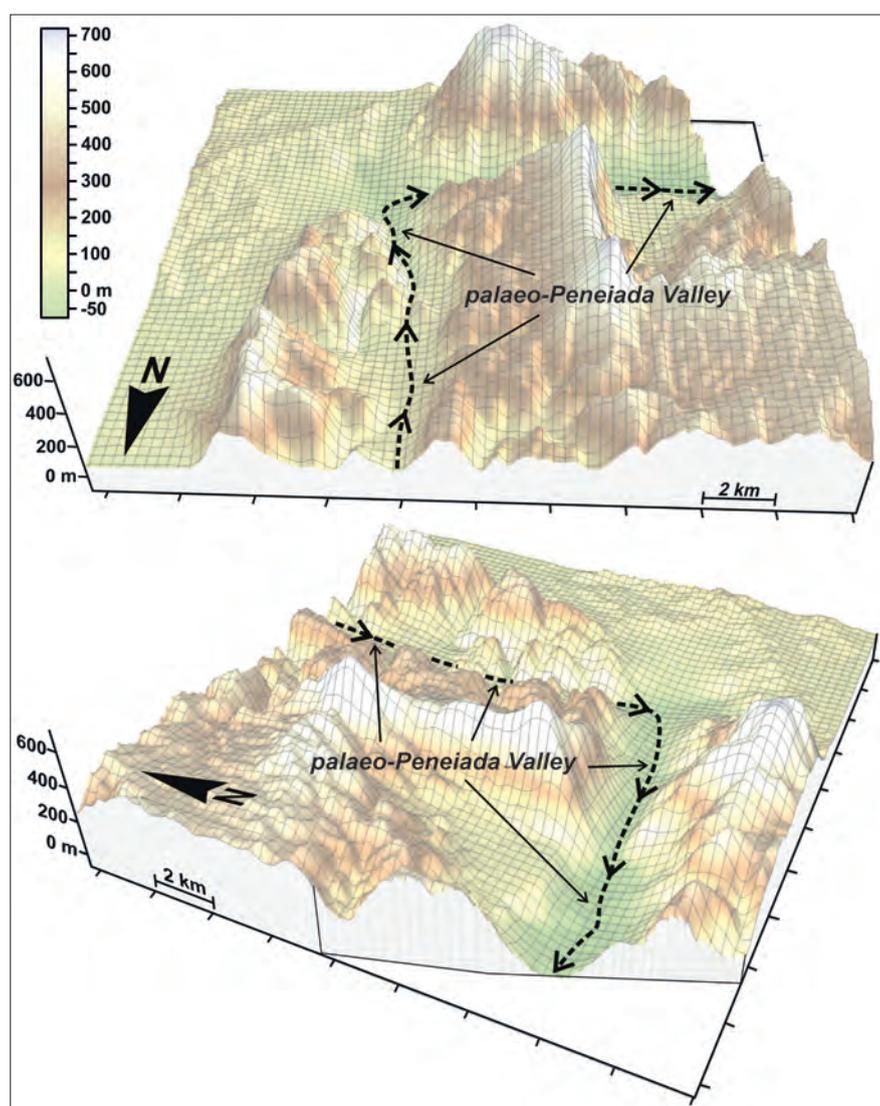


Fig. II.1.4 Three-dimensional model of the palaeo-Peneiada Valley as reconstructed by Mantovani et al. 2018 based on the results of a dedicated geophysical survey. Note that the slope along the bottom of the valley was towards the Karditsa area (R. Caputo)

³⁸ Mantovani et al. 2018.

in the opposite direction from the present-day Peneios River, which nowadays flows on top of the Holocene alluvial plain and drains the waters from western to eastern Thessaly (Fig. II.1.1a and b).

The geophysical survey, based on numerous microtremor measurements (seismic noise), was carried out all over the plain of the Peneiada Valley and it is well calibrated with the available stratigraphy from boreholes, allowing a two-step procedure for 3D interpolation.

Based on these geophysical results and the morphological evidence, it is also clear that the palaeo-Peneiada Valley could not be a secondary chorographic feature of the Thessaly region and was certainly characterised by a correspondingly wide hydrographic basin. By taking into account and carefully inspecting the present hydrographic network of the broader area (Fig. II.1.1a and b), and particularly the drainage area of the major water courses draining the mountains surrounding Thessaly (Fig. II.1.5), it is likely that the palaeo-Peneiada Valley was part of the Titarissios River, representing its lowest hydraulic and altimetric reach before flowing into the Karditsa ‘area’ (Figs. II.1.6a, II.1.7.a). The issue of a possible connection between the Titarissios and Peneios rivers was already raised by Horst Ernst Schneider and Michel Sivignon,³⁹ who, however, did not propose any solution to the question posed.

As a first substantial consequence of this reconstruction, the Karditsa ‘area’ was therefore characterised by an endorheic hydrographic pattern, where the Titarissios River was probably among the most important tributaries (at least considering the extension of the present-day hydrographic basins draining into western Thessaly; Fig. II.1.5). Accordingly, from an environmental point of view, the Karditsa ‘area’ at that time was certainly covered by a water table corresponding to a major lake or at least diffuse marshy zones; the permanence and the size of the inundated surface was obviously also a function of the climatic period (glacial versus interglacial stages) that, during the Quaternary, strongly modulated the regional precipitation regime⁴⁰ and therefore the overall water discharge of the several inlets and tributaries of the western Thessalian ‘lowland’.

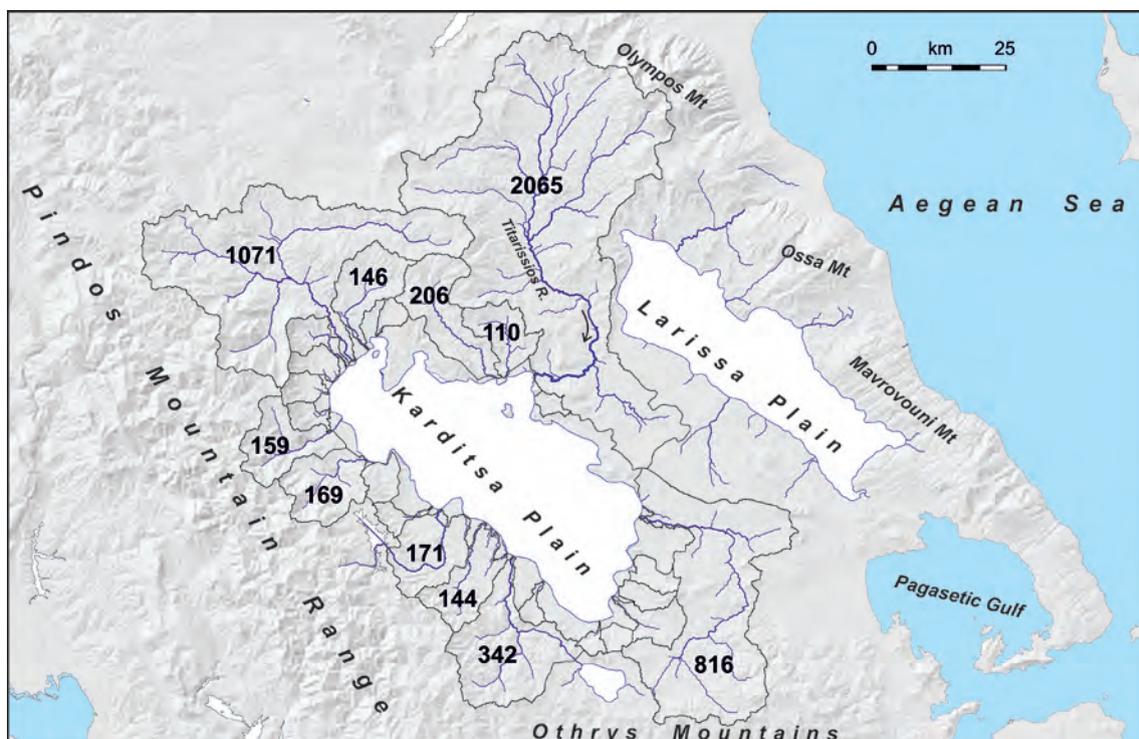


Fig. II.1.5 Hydrographic basins and corresponding areas in km² of the major inlets of the palaeo-Karditsa Lake (R. Caputo)

³⁹ Schneider 1968; Sivignon 1975.

⁴⁰ E.g. Dean et al. 2015.

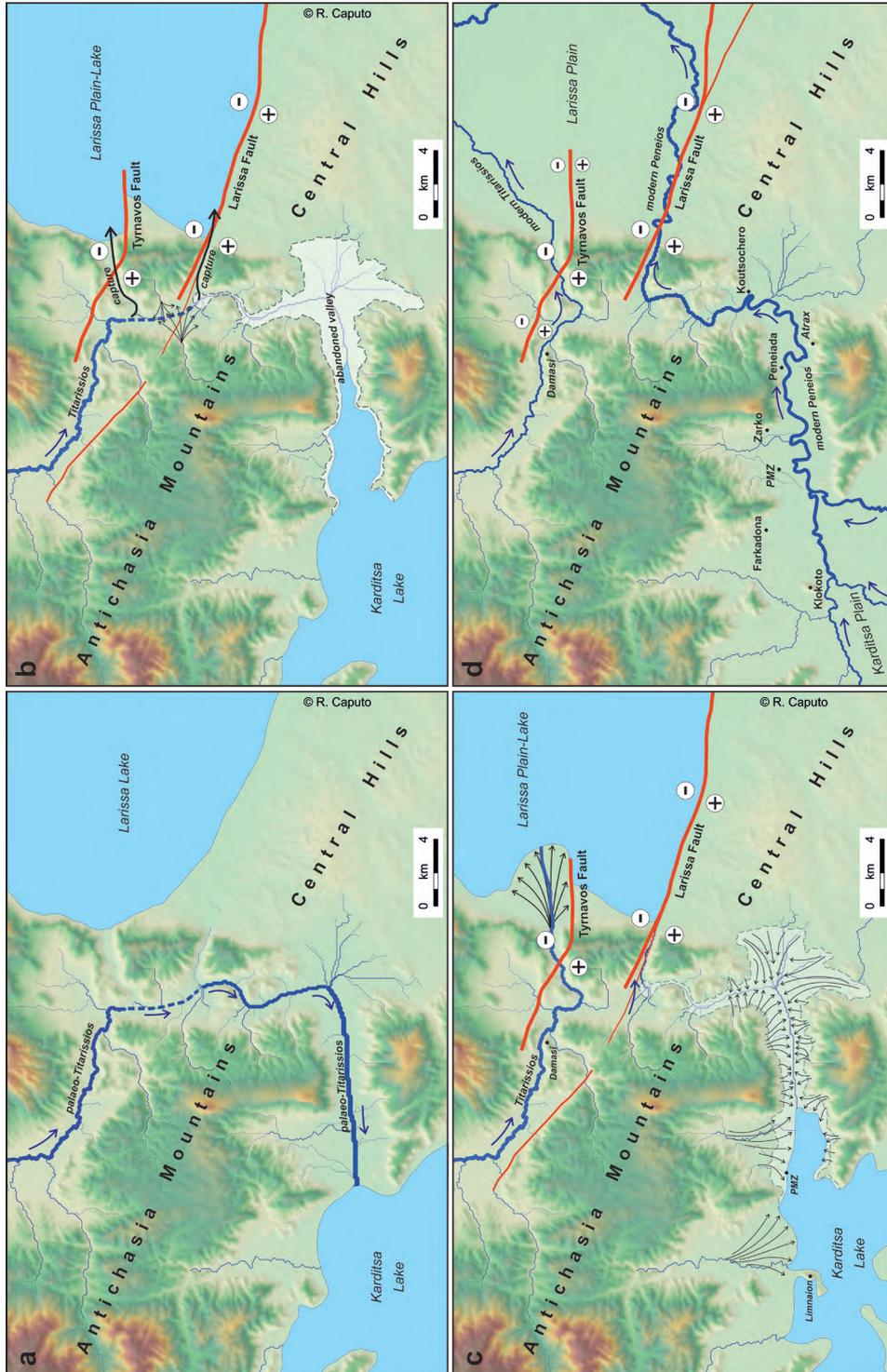


Fig. II.1.6 a. Tentative reconstruction of the main course of the Titarissos River flowing along the palaeo-Peneiada Valley and draining into the Karditsa Lake during the Late Pleistocene; b. Capture phases of the Titarissos River firstly in correspondence with, and due to, the Larissa Fault and subsequently by the Tynnavos Fault, which definitely diverted the waters into the Larissa Lake. At this stage no major watercourse was flowing in the (abandoned) Peneiada Valley; c. In the meantime, the Karditsa Lake was progressively infilled by the sediments transported by the 'western' rivers (Fig. II.1.7). Once the progradation of the internal deltas and the level of the western plain reached the entrance of the abandoned Peneiada Valley the latter was affected by a very high aggradation rate and the consequent rapid inversion of the topographic gradient (thus becoming eastward dipping); d. therefore allowing the 'western' waters to definitely drain into the Larissa Plain sometime during the Holocene and likely in historical time (R. Caputo)

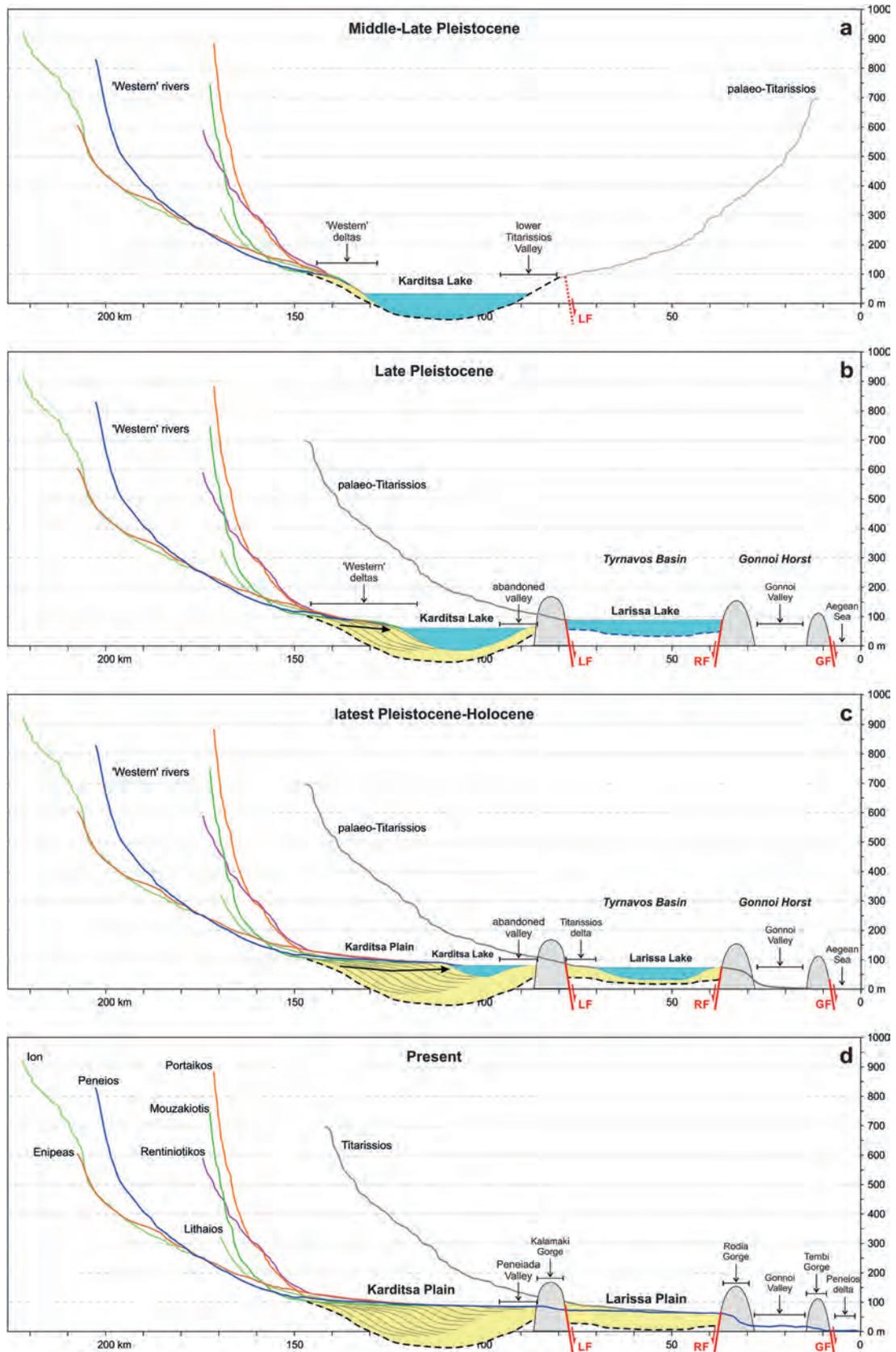


Fig. II.1.7 Evolution of the longitudinal profiles of the major rivers representing the hydrographic network of Thessaly since the Middle to Late Quaternary. The sketches show the progressive infilling of Karditsa Lake (a) by the 'western' rivers as well as the capture of the Titarissios River into the Larissa Lake/Plain (b) and the hydraulic inversion of the Peneiada Valley (d). See text for discussion (R. Caputo)

In this regard, it should be noted that for the eastern Thessalian sector too (Larissa 'area'), a prolonged stage with similar swampy and/or lacustrine conditions has been documented to have occurred during the Quaternary (the so called Villafranchian Thessalian lake).⁴¹ But also later and up to the Holocene, the palaeogeography of eastern Thessaly was still highly dynamic, being governed by the competing roles of i) the active normal faults bordering the Tyrnavos Basin, ii) the fluvial sediment load, mainly the Titarissios and Peneios rivers, and iii) the climate.

Tectonic Influence on the Recent Geomorphic Evolution

Since the (Middle-)Late Quaternary, the broader Aegean region, including Thessaly, has been shaped by an important geodynamic rearrangement.⁴² The new north-south direction of crustal stretching started affecting the pre-existing NW-SE-trending basin-and-range-like structure by creating new normal faults striking obliquely to the inherited ones and trending between east-west and ESE-WNW.⁴³ From a geographic, hydrographic and geomorphological point of view, the major consequence of the new tectonic regime was the progressive disappearance of the Villafranchian Thessalian lake,⁴⁴ which at that time covered most of the two largest basins (i.e. Karditsa and Larissa) and the lower parts of the interposed Central Hills. Coastal deposits (i.e. beach rocks) of this regional-scale Pliocene–Early Pleistocene lake have been largely mapped along the western reliefs of the Larissa Plain.⁴⁵ The present-day altitudes of these deposits are as high as 250–300m and therefore provide an approximate value for the maximum water level of the ancient lake.

As a consequence of this geodynamic rearrangement, in northern Thessaly an ESE-WNW-trending graben started developing (Tyrnavos Basin)⁴⁶ bordered by some (nowadays) major faults. Of particular interest for the present paper is the role played by the Tyrnavos and Larissa faults, strongly interfering with the hydrographic basin of the palaeo-Titarissios River and particularly the palaeo-Peneiada Valley (Fig. II.1.6b). Although the two faults are north-dipping, with normal dip-slip kinematics thus causing the uplift of the southern footwall blocks and the subsidence of the northern hanging-wall blocks, both faults had a different influence and they played different roles, both direct and indirect, on the fluvial diversion and the hydrographic changes that occurred during the Late Pleistocene.

Regarding the Larissa Fault, the repeated occurrence of linear morphogenic earthquakes⁴⁷ rapidly generated a scarp across the riverbed, locally inverting the downstream gradient and therefore gradually hampering the regular southward flow of the palaeo-Titarissios River. Additionally, the repeated coseismic fracturing along the WNW-ESE-trending damage zone of the Larissa Fault could have contributed to i) mechanically weakening the rock formations, ii) greatly increasing their erodibility and permeability and thus iii) concentrating the entrenchment process by channelised waters towards the east (Fig. II.1.6b). As a consequence of the local water accumulation (i.e. damming effect by the fault) and the fast regressive erosional phenomena ('climbing' from the Larissa lake) a proto-Kalamaki Gorge could have formed, possibly causing a first diversion event for the palaeo-Titarissios River.

On the other hand, the growing cumulative displacement on the contemporaneously forming Tyrnavos Fault had two major indirect effects. Firstly, the 3–4km-long reach of the Titarissios River flowing parallel to the fault trace on top of the continuously uplifted footwall block suffered a rapid decrease in its downstream gradient. Secondly, corresponding to the major tectonic

⁴¹ Caputo et al. 1994.

⁴² E.g. Mercier 1981; Mercier et al. 1989; Caputo – Pavlides 1993.

⁴³ Caputo 1995.

⁴⁴ Caputo et al. 1994.

⁴⁵ Caputo 1990.

⁴⁶ Caputo 1990; Caputo 1995.

⁴⁷ Senu Caputo 2005.

scarp induced by the Tyrnavos Fault, with a maximum effect in its central sector, the local north-eastwards topographic gradient was increasing together with the displacement accumulation and therefore the concentrated local energy of the surficial waters could have induced rapid regressive erosion, finally reaching, and thus capturing, the Titarissios River east of Damasi and thereby generating its present-day path and starting to form a rapidly prograding internal delta (Fig. II.1.6c).

We do not know the exact timing of this two-step capture process; however, the permanent diversion of the palaeo-Titarissios River towards the ENE, definitely draining its waters into the Larissa ‘area’ certainly occurred sometime during the Late Pleistocene. As a further consequence of either of these two major hydrographic changes, the lower reach of the palaeo-Titarissios River corresponding to the Peneiada Valley was then completely abandoned. Only a very local hydrographic network possibly exploited the valley at that time (Figs. II.1.6c, II.1.7b).

Sedimentary Infilling of the Abandoned Valley

From the geophysical investigations,⁴⁸ the deposits overlying the bedrock of the palaeo-valley have a maximum thickness of about 150m south of Farkadona, progressively decreasing towards Koutsochero and becoming nil west of the Kalamaki Gorge (Fig. II.1.4). The lower part of this sedimentary succession was possibly accumulated by the same palaeo-Titarissios River when it was contributing to the general infilling of the Karditsa Lake particularly during periods characterised by a higher base level likely corresponding to climatic wet stages. These lacustrine, fluvial and/or internal delta depositional conditions likely persisted through the Middle and Late Pleistocene.

However, once the definite diversion(s) occurred upstream and the Peneiada Valley was permanently abandoned by the Titarissios River, the depositional process likely suffered an important slowdown. Indeed, the major sedimentary contribution was only represented by the lateral ejection cones originating from, and descending the numerous minor valleys more or less deeply entrenched in the slopes of the Mesozoic carbonate massifs bordering the Peneiada Valley along its entire length (Fig. II.1.6c). On the other hand, the lack of a major water course flowing along the bottom of the valley could have had the effect of facilitating the growth of the ejection cones (viz. progradation) insofar as there was no longer sufficient energy to hydraulically remove from their toe the coarse-grained clasts, as otherwise regularly occurred during the flow of the palaeo-Titarissios River. During the Late Pleistocene glacial periods, these cones probably experienced their maximum development and progradation rate (Fig. II.1.6c).

In the meantime, the western rivers draining the Antichasia, Pindos and Othrys mountain ranges and cumulatively representing a very large drainage area (Fig. II.1.5) were causing a growing eastwards hydraulic and sedimentary ‘pressure’ in their search for an outlet towards the Aegean Sea (Fig. II.1.7b). This was due to the persisting continental collision along the western Hellenides and the consequent rapid uplift of the Greek mountain ranges, preventing a general drainage towards the Ionian Sea of the largely emerged areas of western Macedonia and Epirus. Depending on water discharge, which, conversely, was a direct function of climate, all these rivers mainly accumulated their sedimentary load within the Karditsa Basin, prevailing in its southern, western and northern sectors (Fig. II.1.1a) producing coalescent internal deltas (Fig. II.1.7b) and thus generating a large scale mean gradient towards E-NE, still clearly visible in the digital elevation model (DEM) and in all profiles of the rivers flowing in the Karditsa Plain (Fig. II.1.1b). During the latest Quaternary, the western rivers progressively reached the entrance to the Peneiada Valley close to Farkadona (Fig. II.1.7c).

Following the diversion of the Titarissios River, the consequent lack of i) any counteracting westward flow, ii) any associated hydraulic gradient and iii) westward sediment transportation certainly facilitated and accelerated the very final infilling stages of the palaeo-Peneiada Valley

⁴⁸ Mantovani et al. 2018.

from the west towards the east (Fig. II.1.7d). Indeed, due to the limited width of the valley compared to the Karditsa Plain and to the huge sedimentary input of western provenance (Fig. II.1.5), this process likely occurred in an extremely rapid way. Once progradation and aggradation of the palaeo-Peneiada Valley floor reached the threshold altitude north of Koutsochero, the proto-Kalamaki Gorge that was likely already formed along the Larissa Fault during the Late Pleistocene (first Titarissios River diversion; Fig. II.1.6b) could have been exploited by the 'western' waters to establish a direct hydraulic connection with the Eastern Thessalian Plain (Fig. II.1.6d). With this last event, the flow direction along the Peneiada Valley was therefore definitely reversed (Fig. II.1.7d). This ultimate event occurred in (latest Pleistocene–)Holocene times, as will be discussed further in the following section. Only at this stage, did the Karditsa Plain and its entire hydrographic basin begin to drain permanently eastwards, as we see them today (Fig. II.1.1a). At that time, the Larissa Plain was probably already connected to the Aegean Sea across the Rodia Gorge and the Tembi Valley (Fig. II.1.7c),⁴⁹ thus setting up the entire path of what we today call the Peneios River.

The renewed water flow across the Kalamaki Gorge and the greatly increased water discharge along the very narrow valley consequently resumed entrenching and river regressive erosion, this time to facilitate the evacuation of the 'western' waters. Such erosion progressively shifted upstream the equilibrium point along the newly formed Peneios River. At present, the critical disequilibrium sector separating the upstream reach, where frequent flooding events still occur, contributing to a residual (though progressively disappearing) aggradation of the Peneiada Valley plain (Fig. II.1.3), and the downstream reach, where, instead, vertical entrenching by the riverbed started prevailing, is somewhere between Peneiada and Koutsochero villages. This is documented by the coexistence of persisting inundation periods and the riverbed being 5–8m deep relative to the surrounding alluvial plain.

Age of Ejection Cones

Regarding the age of the late sediment infilling of the palaeo-Peneiada Valley and the final inversion of the water flow direction, no absolute ages are available at present. However, in this section we discuss some chronological constraints by analysing the ejection cones originating from the several minor lateral valleys (Fig. II.1.2). Their morphological analysis based on direct field observations and high resolution DEMs indicates that all these cones are characterised by a quite regular slope with typical fan geometry in map view and a smooth topographic surface uniformly sloping from the lateral valley mouth(s) in the bedrock towards the plain.

It should be noted that macroscopic differences exist between the ejection cones whose hydrographic basins consist exclusively of Mesozoic carbonate rocks, from those characterised by prevailing Palaeozoic metamorphic rocks, mainly schists and gneiss. Indeed, the degree of erodibility of these two lithologies is quite different, but in particular, the average dimensions of the clasts produced along the mountain slopes from the two source rocks is very different: the former generally coarse grained (with clasts up to some cm) and matrix-poor; the latter fine grained (with clasts of at most a few mm and generally much less) and matrix-rich. On the other hand, the different degree of erodibility caused the rocky slopes in the metamorphic basins to retreat much faster, therefore widening the corresponding secondary hydrographic networks and hence further increasing the amount of eroded material.

These differences, both in the granulometry and in the amount of clasts produced, as well as the overall textural features of the deposits, are obviously reflected in the slope angle of the associated cones: generally greater for carbonate-sourced fans (5°–10°) and smaller for the other ones (1°–2°); similarly, the overall size of the fans is much smaller for the former and wider for the latter ones.

⁴⁹ Caputo et al. 1994.

Also, the solute carbonate content in the water draining the ‘carbonate’ versus the ‘metamorphic’ hydrographic basins was markedly different, and this hydrochemical difference consequently induced a different degree of cementation for the two types of cones, especially during the glacial maxima, including the last one at c. 26.5–19.5ka BP. This is because the increased precipitation during these climatic peaks similarly increased the dissolution of the carbonate rocks uphill and hence the hydrochemistry of the fed aquifers, especially the shallow ones, was richer in solute calcium.

On top of the cones we nowadays observe a soil, generally 1–2m thick, with only a minor colluvial input. No active debris phenomena or scree deposits are observed on top of these surfaces. That is to say, the rocky slopes impending over the cones within the corresponding hydrographic basins at present do not produce clasts to be subsequently transported downhill and therefore they no longer contribute to the growth of the cones. In other words, and similar to most of the Aegean realm and other Mediterranean regions, the mountain slopes, especially the carbonate ones, have basically been stable since the fading of the last glacial maximum (LGM), say during the last 15–18ka. This is well documented in the literature and the late LGM topography is commonly exploited as a chronological marker in many morphotectonic and palaeoseismological investigations.⁵⁰ Similar cemented deposits in Thessaly characterising the upmost layers of the ejection cones provided ¹⁴C ages of 19–23ka,⁵¹ in perfect agreement with the age of the LGM. On the other hand, it should also be noted that the uniform granulometric and textural characteristics of the deposits as well as the morphological similarity of the different cones all along the Peneiada Valley, and in Thessaly more broadly, suggest a common genetic process and a common age formation.

Another crucial observation relative to the lateral ejection cones and their chronology is represented by their stratigraphic and geometric relationships with the fluvial-marsh deposits topping the Peneiada Valley plain. If we assume as a null hypothesis that both depositional environments (i.e. slope and flooding plain) were contemporaneously active, the two markedly different facies (ejection cones versus alluvial sediments) and the associated event layers should basically interfinger at the foot of the Peneiada Valley flanks where the progradation of the cones and the aggradation of the plain would compete and their effects would merge. As a consequence, on the topographic surface we should observe a sort of transition zone between the two sedimentary environments expressed in the topography by an interposed slope connecting the regularly dipping ejection cones (5°–10°) with the horizontal alluvial plain. In other words, at the toe of the cones we should systematically observe a belt characterised by a progressively decreasing gradient.

Contrary to the null hypothesis, this morphological feature is not observed at all along the Peneiada Valley’s sides and the slope angle changes abruptly from that typical of the cones (i.e. 5°–10°) to the flat topography of the alluvial plain. To sum up, a first major conclusion we could infer is that the activity of the ejection cones clearly pre-dates the last infilling stage of the Peneiada Valley. As a consequence, and taking into account the fact that the cones largely completed their evolution during the LGM (c. 26.5–19.5ka BP), the final infilling phase and the ultimate progradation-aggradation event(s) within the alluvial plain that ultimately generated a stable, though subtle, eastward topographic gradient of the Peneiada Valley plain, mainly occurred during the Holocene (Fig. II.1.7d). Only at this stage, was a permanent hydraulic-hydrographic connection from the Karditsa Plain to the Larissa Plain established via a water course that we today call the Peneios River.

⁵⁰ Benedetti et al. 2002; Papanikolaou et al. 2005; Caputo et al. 2006; Caputo et al. 2010; Mason et al. 2016.

⁵¹ Caputo – Helly 2007.

II.1.3. Environmental Changes in the Post-Last Glacial Maximum Period

Early Holocene Changes

Immediately following the LGM, say for some/few thousands of years, the lack of, or the very reduced, vegetation cover had two major consequences. Firstly, large amounts of loose material were produced on the mountain slopes (i.e. in the upper parts of the drainage basins) and easily transported downstream through the hydrographic network. Secondly, due to the prevailing surface rilling and the poor underground infiltration along the slopes, most of the precipitation water was quickly transferred towards the lower hydrographic network, thereby increasing the water discharge in the channels and hence their energy. At the dawn of the post-LGM period, the combination of these two effects (high sediment load and high water discharge) probably found an equilibrium by transferring most of the sediment load down to the local base level, thereby building rapidly prograding internal deltas (Fig. II.1.7b–c).

Sometime later, the progressive climate change towards overall warmer conditions and the concurrent diffusion of the vegetation cover in the broader Mediterranean realm, and particularly in Greece, had some major consequences. Indeed, i) the water discharge in the lower channels (i.e. in the alluvial plains) experienced a slight reduction, ii) the production of clastic material in the mountain slopes was similarly reduced, but especially iii) large amounts of these materials were deposited in the wide alluvial cones/internal deltas starting to develop from the border of the Karditsa Plain and progressively prograding towards the Peneiada Valley entrance.

Due to the eastward restraining of the Peneiada Valley, the progressive alluvial infilling was even faster towards the Kalamaki Gorge with respect to the valley entrance close to Farkadona. In this regard, the occurrence of very rapidly prograding internal deltas has been well documented in the Po Plain, North Italy, associated with the large amount of material discharge caused by the Apennine tributaries.⁵² For example, in historical times, local aggradation and progradation rates as high as 15cm/a and 500m/a, respectively, have been documented for the Reno River,⁵³ but similar ones could be inferred for other nearby Apennine rivers. Taking into account that the hydrographic basin of the Reno River is comparatively much smaller than the source area of the 'western' rivers at the entrance to the Peneiada Valley (Fig. II.1.5), during the post-LGM wet periods it is reasonable to assume comparable aggradation rates.

It should also be considered that the post-LGM period was also repeatedly affected by minor fluctuations of climatic conditions and particularly by several global cold epochs generally associated in central Greece with i) wetter conditions, ii) higher precipitation, iii) longer flooding periods, and iv) likely much more intense rainy events.⁵⁴ These conditions were favourable to more frequent and stronger exudation events and the consequent distribution and deposition of huge amounts of alluvial sediments in the surrounding flat topography. Insofar as the Peneiada Valley is particularly narrow, the infilling process and consequent aggradation of the valley floor could have been characterised by periods of accelerated sedimentation rates up to several mm/a (or even some cm/a).

Neolithic Period

Latest Palaeolithic and certainly Neolithic people lived in a rapidly changing environment. Indeed, that was the time span during which the Peneiada Valley was definitely infilled by progradation-aggradation, thus transforming from lacustrine-marshy conditions to the permanently established eastward water drainage. The latter stage is strictly associated with the formation of the modern

⁵² Amorosi et al. 2014; Caputo et al. 2016.

⁵³ Bondesan 2001; Caputo et al. 2016.

⁵⁴ Rossignol-Strick 1993; Kromer – Friedrich 2007; Ceraga et al. 2010; Dean et al. 2015.

Peneios River (Figs. II.1.1, II.1.5) transporting the ‘western’ water into the Larissa Plain and from there finally to the Aegean Sea, forming the present marine delta.

From a dynamic point of view, two distinct processes operated synergistically on the hydraulic-topographic gradient of the Peneiada Valley in order to facilitate the water flow from the Karditsa Plain towards the Larissa Plain. These processes were, firstly, the progressive regressive erosion along the Kalamaki Gorge (and subsequently the upstream reaches) and, secondly, the progressive progradation-aggradation within the Peneiada Valley from the west towards the east. As a consequence, once an eastward-dipping gradient was definitely established (Fig. II.1.7d), the seasonally and/or permanently flooded areas within the Peneiada Valley began to reduce together with the frequency of the exceptional flood events affecting the intermountain plain. In such newly evolving environmental conditions, contemporaneous people assisted a sort of regression of the lacustrine zone, a migration of the swamp area and a retreat of the associated ‘coastline’.

Assuming as a preliminary and rough hypothesis that the amount of water seasonally flooding the Peneiada Valley plain during rainy periods and/or snow-melting periods was more or less constant during some generations of the Neolithic people, the inundated surface and the depth of the water could have been similar year on year. What changed progressively through generations, however, was the absolute altitude of the aggrading alluvial plain, consequently the extent of flood water and therefore the absolute altitude of the ‘coastline’ of the seasonally inundated areas. In other words, Neolithic people could have passively assisted a sort of swamp/lake transgression towards their villages and farmed areas.

Considering also annually variable floods and taking into account the 1-year, the 10-year and, for example, the 50-year water discharge maximum events, from the inhabitants’ perspective it was like observing that exceptional inundation events, in terms of water extent, water current (viz. energy) and maximum water depth, were progressively increasing in frequency and magnitude during their lifetime. It is, therefore, obvious that in such conditions the most reasonable solution was to move their villages to a higher, safer and drier location, however still close to the seasonally fertilised farmed areas and the vital water supply.

This is what probably occurred sometime between the Early and the Middle Neolithic, say around 7.8ka BP (i.e. 5.8ka BC), when Magoula Koutsaki was abandoned⁵⁵ and PMZ was settled more or less contemporaneously. The detailed archaeological stratigraphy at this site documents that this settlement was characterised by a continuous occupation up to c. the end of the Middle Neolithic, when it seems it was suddenly abandoned until it was re-occupied during the Bronze Age.⁵⁶

It is worth noting that PMZ is located at the toe of the widest ejection cone formed along the northern flank of the Peneiada Valley (Fig. II.1.8). As mentioned in a previous section, this is one of the cones of ‘metamorphic’ provenance consisting of matrix-rich, fine-grained (with clasts up to few millimetres in size) deposits mainly associated with debris-flow transport mechanisms. Such locations could be generally quite safe, especially if ditches and protection walls are installed;⁵⁷ however, in the case of exceptional events (e.g. flash floods) directed by natural fan channel migration and by chance straight towards the archaeological site, the destructive power of these natural phenomena could be locally catastrophic, generating a depositional strip several kilometres long, up to 1–2m thick and 100–200m wide. A similar morphological feature can be clearly observed nowadays south of Zarko village. Such an event could have potentially forced Neolithic people to move away from the site.

⁵⁵ Giorgos Toufexis, personal communication.

⁵⁶ Gallis 1989; Toufexis – Batzelas, this volume, 83, 125.

⁵⁷ Souvatzi, this volume, 593–596.

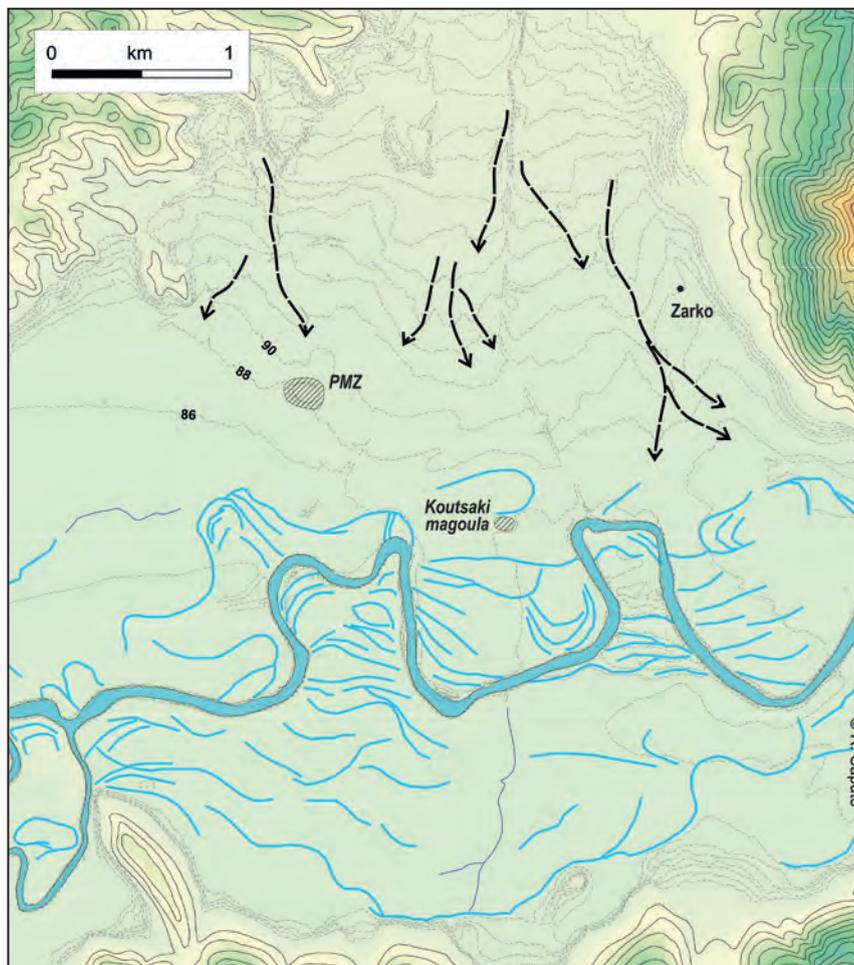


Fig. II.1.8 Map of the Zarko area showing the location of the Neolithic sites PMZ and Koutsaki Magoula. Blue lines represent palaeo-channels and point bars; dashed arrows indicate possible recent (Late Holocene?) flash floods. The altitude of selected contours is reported. Koutsaki Magoula and PMZ were both likely located close to the coastline of the palaeo-lake at different stages (viz. epochs). The former has been partially draped in historical time by the fluvial deposits of the modern Peneios River (R. Caputo)

River Dynamics Deduced from Historical Floodplain Features

We have been able to identify late Holocene and modern fluvial features in the Peneiada reach floodplain (Fig. II.1.9). The three distinct units are the following: i) A first unit developed on the northern side of the Peneiada Plain may correspond to deposits originating from the northern slopes and reworked by water dynamics during the highest stage of the former lake. This unit may date back at the latest to the complete infilling of the lake by the eastward prograding internal delta; ii) An intermediate unit sloping to the east once the Kalambaki Gorge allowed regressive erosion westward into the Peneiada Valley floor. Unit 2 of the Peneios alluvial plain displays ancient oxbow lakes (cut-off and isolated) belonging to one or several meander belts of different ages on the northern margin of the alluvial plain; for example, oxbows near Peneiada have been documented on aerial photos.⁵⁸ The geographic isolation of palaeomeanders may have prevented the Peneios floods from completely filling them with sediment. The convex part of the meanders displays a series of arcuate scroll bars corresponding to a succession of meander shifting stages

⁵⁸ Tziafalias et al. 2016.

during flood episodes. West of Peneiada village, unit 2 is located south of the modern meander belt, while east of Peneiada, a stretch of meander pattern is located north of the modern meander belt. As a result, the shifting of meanders during the early Holocene would have released a considerable quantity of sediment towards the Kalambaki Gorge. The shifting of the meanders may have been all the more rapid as the river was not yet entrenched and the recent fluvio-lacustrine sediment was soft; iii) The present Peneios is an active incised river located in a meander belt, displaying compound meanders, discrete active features of lateral erosion and lateral features built up by the river lateral migration, like small bars (unit 3).

Archaic to Roman Period

A more recent archaeological site settled along the Peneiada Valley provides crucial information on the rapidly evolving hydrography and morphology of the area. It is represented by Atrax (Figs. II.1.2, II.1.9), one important town of the Thessalians from Archaic to Roman Thessaly (7th–2nd centuries B.C. ~2.7–2.1ka BP). The site was also occupied during Roman and early Byzantine times (till c. the 10th century) but its importance was clearly reduced. The site is located on the southern side of the valley and during its maximum expansion it occupied 90 hectares.⁵⁹ In particular, the core of the town (*acropolis*) was located in the lower sector of the bedrock slope of Mount Titanos, the more rural area (*katopolis*) extended over the lower part of the nearby ejection cone, while the farmed area was distributed in the contiguous alluvial plain just north of it (Fig. II.1.9).

A wall surrounding the city of Atrax was constructed with large quadrangular blocks; well shaped, they displayed corner rabbits. These features allow us to date the wall to the 4th century BC, a period during which Thessaly was allied (in fact submitted) to the Macedonian kings. In its NW corner, the wall extended down to the river channel. The stone structure has been interpreted as a large barbican ending with two square towers meant to impede access to the narrowest route down the hill and to ensure direct access to water. There it may have been the head of a wooden bridge, despite the fact that no remnant has been preserved on the opposite bank of the river.

At that time, the lake as a permanent water table had certainly already disappeared due to the establishment of stable drainage towards the Larissa Plain via the Kalamaki Gorge; nonetheless, seasonal flooding events affecting the Peneiada Valley bottom were relatively frequent (as they still occur today; Fig. II.1.3). If the urbanisation of the acropolis had mainly strategic reasons, the ‘down-town’ and agricultural areas were settled on a ‘terraced’ sector of the Peneiada Valley, and from this point of view, villagers were likely safe enough from major flooding events.

During Classical times, the necropoleis like those of Atrax, were commonly aligned along major roads and not grouped into cemeteries. In this regard, several tombs are more or less still at the surface around Atrax and well documented by archaeological surveys,⁶⁰ east, north, and west of the town, thus suggesting the existence of three roads, respectively (Fig. II.1.9). Two main sites of archaeological findings have been documented so far on the surface of the modern plain. Firstly, eight funeral steles with engraved epitaphs dated 4th–3rd centuries BC have been described at Lithodokia (the ‘stones deposit’), between Peneiada and Koutsochero. These steles have been reused in a collective tomb dated to the Roman period thanks to the discovery of coins; the tomb could be posterior to the 1st century AD. Three corpses were present in the tomb.⁶¹ On the occasion of the widening of the Larissa-Trikala road, 36 tombs were discovered at the same site, referred to as Palaiopigado, and described by Stella Katakouta.⁶² These tombs of various types were dated as Hellenistic and Roman and included small vases and artefacts. This necropolis was probably connected with Atrax thanks to a road crossing the alluvial plain.

⁵⁹ Tziafalias et al. 2016.

⁶⁰ Chourmouziadis 1968; Tziafalias et al. 2016.

⁶¹ Gallis 1979a.

⁶² Katakouta 2001.

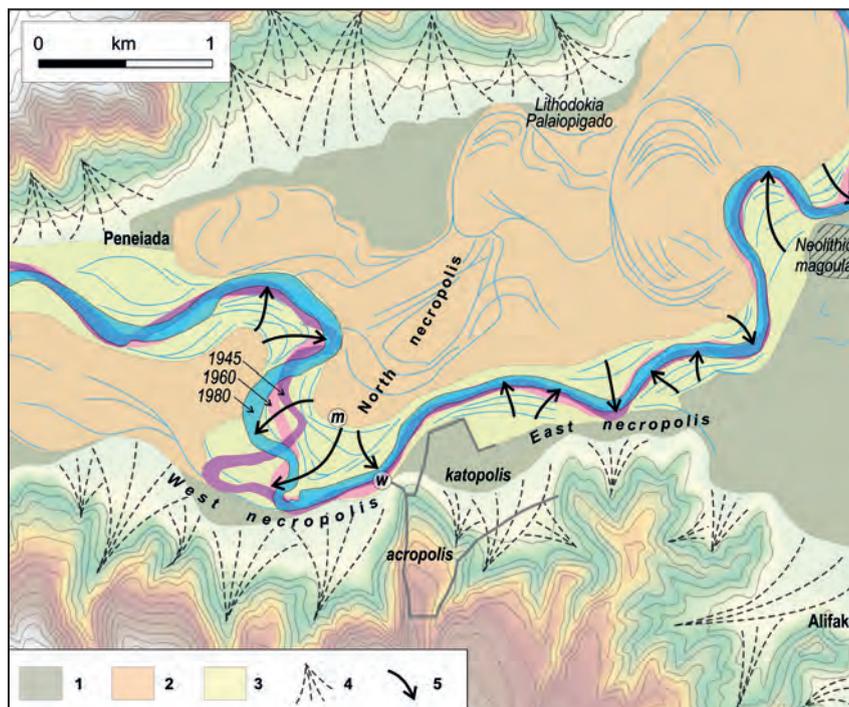


Fig. II.1.9 Map of the archaeological site of Atrax, southeast of Peneiada village, along the northern slope of the Titanos Mount, showing the location of the acropolis, the katopolis (downtown) and the necropoles surrounding the city along the pathways to Trikala (West), Ellassona (North) and Larissa (East). 1. highest terrace (Early to Mid Holocene); 2. intermediate terrace (prehistorical); 3. lowest terrace (historical); 4. ejection cones (LGM); 5. direction of historical meander shift. The different paths of the Peneios River are labelled by the year of the source topographic map (R. Caputo)

Secondly, the so-called North necropolis was discovered in 1972–1974 in a former channel visible in the cultivated alluvial plain north of Atrax, on the left bank of the modern Peneios (Fig. II.1.9). It may have been located along the road running from Atrax to Lithodokia. Before it was destroyed by farming, the necropolis yielded tombs and the large base of an equestrian statue,⁶³ with inscriptions related to a leading soldier and probably a citizen born in Atrax. This person had been a Thessalian strategist and a benefactor of the city; the statue was probably erected just after he left office, when he was still alive. The inscription may be dated to the 3rd century BC or more probably early 2nd century BC. The base of the statue stood at the same place until the late Roman period at least, as testified to by another inscription, a slave manumission act, dated mid-2nd century AD.⁶⁴

Since then, the southwestwards lateral migration of the major meander located NW of the town (arrow from point *m* in Fig. II.1.9) has reworked the top 6–8m of sediments of this sector of the plain, thereby completely wiping out any possible trace of archaeological remains. As a consequence, some of the tombs from the northern and western necropoles have probably disappeared.

On the other hand, the surface location of the tombs suggests that sedimentation since then was quite limited. This observation and the fact that the present-day bed of the Peneios River in this sector of the Peneiada Valley is entrenched several metres in the alluvial plain suggest that regressive erosion from the Kalamaki Gorge has already affected this reach of the river, permitting a better and quicker drainage of the excess water during floods.

⁶³ Tziafalias et al. 2016 (*I. Atrax*, no. 151).

⁶⁴ Tziafalias et al. 2016 (*I. Atrax*, no. 48).

Relationship between Fluvial Patterns and Historical Archaeological Sites

The meandering process in this sector of the Peneiada Valley seems to have slowed down since at least the 3rd century BC as the necropolises established during the 4th century BC are still largely visible at the surface. Accordingly, most abandoned meanders and other hydrographic features associated with unit 2 are certainly older, while further meandering in the sector of the plain close to Atrax was quite reduced and limited to unit 3. Nevertheless, floods and some riverbed shifting have certainly destroyed the towers connected to the defence walls that collapsed into the rivers. In modern times, remaining blocks were possibly used to build a ‘daliani’, a V-shaped traditional structure which has been used for catching fish for centuries.⁶⁵

The change in hydraulic behaviour during the last two millennia was also marked by a deep entrenching of the riverbed into its own alluvial deposits, likely a consequence of an excess of energy. Excess energy could be locally and/or temporarily available as a consequence of external (to the river) processes and phenomena, like changes in the climate and/or tectonic activity. Within the investigated area, this natural phenomenon was possibly triggered by the regressive upstream erosion that, starting from the Kalamaki Gorge several thousand years before, finally reached this sector of the plain, causing a relative increase in the slope and meander stability.

Environmental History Deduced from Ancient Texts

Although, from a geological point of view, the important environmental change from lacustrine-marshy to fluvial conditions was quite rapid, it certainly took place over a time span much longer than a single human generation. Nonetheless, the memory of such natural variations could have been fixed as an oral tradition, thus becoming a myth. For example, the historian Herodotus (5th century BC) reports the ‘logos’ that “Thessaly, as tradition has it, was in old times a lake enclosed all round by high mountains. On its eastern side it is fenced in by the joining of the lower parts of the mountains Pelion and Ossa, to the north by Olympus, to the west by Pindus, towards the south and the southerly wind by Othrys. In the middle, then, of this ring of mountains, lies the vale of Thessaly”.⁶⁶ He also added that “[...] the Thessalians say that Poseidon made the passage by which the Peneus flows. This is reasonable, for whoever believes that Poseidon is the shaker of the earth and that rifts made by earthquakes are the work of that god will conclude, upon seeing that passage, that it is of Poseidon’s making. It was manifest to me that it must have been an earthquake which forced the mountains apart”.⁶⁷ As a good rationalist and beyond the reference of the Thessalians’ myth, he interprets it by stating that an earthquake could have caused the breaking of the mountains surrounding Thessaly, therefore generating a gorge called Tembi and hence the emptying of the older lake.⁶⁸

The same oral tradition is reported by the geographer Strabo (1st century BC) with the same explanation, while another historian, Baton of Sinope (late 3rd century BC) gives a more detailed account of this myth: “the Thessalians received this tradition from the mouth of a divine envoy, who informed the Thessalians that the history of their country is older than they think.” In this regard, the author writes: “In the land of Haimon (prior name of Thessaly), following violent earthquakes, the mountain range called Tembi had been fractured and by this cutting had forcefully drained all the waters of the lake (which then occupied the country) in the direction of the course of Peneus (actual river); all the territory formerly lacustrine had been discovered and, thanks to the continuous drying up of the waters, it had become a plain of magnificent size and beauty”.⁶⁹

⁶⁵ Helly 1991; Helly 1999.

⁶⁶ Herodotus, Histories 7.129.1.

⁶⁷ Herodotus, Histories 7.129.4.

⁶⁸ Helly 1987.

⁶⁹ Fragment conserved by Athenaeus, Deipnosophistai 14.45.

The above citations make it clear that the Thessalians contemporaneous with the authors did not directly see the lake, nor its disruption by an earthquake, but the persistence of the myth on these issues up to the 5th–1st centuries BC confirms that the lake certainly was still clearly visible some generations before, possibly corresponding to some centuries, or at most a millennium. On the other hand, a large literature documents that tectonic activity affected Thessaly during the Holocene, with several major seismic events in historical times,⁷⁰ thus also confirming the myth.

An additional argument supporting a highly dynamic environment in historical times is the foundation at the beginning of the first millennium BC (i.e. c. 3.0ka BP) of a town called Limnaion, whose meaning in ancient Greek could be translated as ‘lacustrine’ or ‘town on the lake’.⁷¹ Based on the same narration by Livy, the broader location of this site could be constrained in the northeastern corner of the Karditsa Plain, close to the entrance of the Peneiada Valley, that is to say in the northeastern corner of the Karditsa Plain east of the major town of Pelinna. Following the proposed morphological and palaeogeographic evolution of the broader area during the Holocene, this is not a surprise and we tentatively correlate this historical town with the archaeological remains found on the hill above the Klokoto village near the modern Farkadona (Fig. II.1.6c–d).⁷² Accordingly, it seems that up to historical times the entrance of the Peneiada Valley still represented, and caused, an overall ‘dam effect’ for the western waters in their attempt to reach the Aegean Sea, via the Larissa Plain, therefore locally and at least periodically accumulating in this sector of Thessaly to generate more or less wide lacustrine-to-marshy water tables.

River Behaviour during the Ottoman Period

With regard to modern times, we focus on two observations. Firstly, a detailed analysis of aerial photos and small-scale topographic maps (1:5,000) allows us to emphasise the occurrence of sand deposits in the internal part of some of the meanders, but especially the presence of small islands even in linear sectors of the riverbed. These sedimentary and morphological features could represent an incipient, though aborted, further transition of the river’s behaviour from a meandering pattern towards a braided pattern (Fig. II.1.8). Indeed, in the present-day climatic conditions, such a perturbation of the hydrographic system could not be explained. We interpret it as a consequence of the Little Ice Age (14th–19th centuries) that likely caused initial forcing conditions, but whose duration was not sufficiently long to make this change complete and permanent.

A second observation is from the centre of the Koutsochero Basin NE of Alifaka village (Fig. II.1.2), where in the topographic maps of the Military Geographic Service (both 1:50,000 and 1:5,000 scale) the toponym ‘Asmaki’ is marked in correspondence with a geodetic point (quoted 82.45m) and the same name is applied to a small watercourse. It is worth noting that the very same word is also used in the Larissa Plain, NE of Larissa to indicate a ‘recent’ natural channel that was rapidly entrenching the Chasambali Bulge, which separates the so-called Nessonis Lake area from the Eleftherai Basin.⁷³ Although ephemeral, the critical role of the ‘eastern’ Asmaki River was a natural attempt at diverting the excess water during flooding periods of the Peneios River towards the southeastern sector of the Larissa Plain, potentially infilling Lake Karla, whose present-day altitude is 44–45m asl, that is, well below the 63–65m asl of the Chasambali Bulge as well as of the definitive exit of the Peneios River across the Rodia Gorge (c. 60m asl).

Although we do not know for sure, it is, however, likely that, based on ethnography, the same toponym in different localities describes the same topographic, morphological and/or hydrographic characteristics. Accordingly, during the Ottoman Empire occupation, local people likely identified the site Asmaki near Alifaka with the same geographic and hydraulic meaning it has

⁷⁰ Caputo 1995; Caputo et al. 2004; Caputo – Helly 2005a; Caputo – Helly 2005b; Caputo et al. 2011.

⁷¹ Titus Livius 36.13.9.

⁷² Decourt 1990.

⁷³ Caputo et al. 1994.

in the Larissa Plain. In other words, understanding and characterising this sector of the alluvial plain as a transfer zone or by-pass area of water during flooding events of the Peneios River in the Peneiada Valley.

If this is the case, the flat area south of Koutsochero represented a natural overflow basin, where both inflow and outflow probably occurred along the Asmaki watercourse up to modern times.

II.1.4. Concluding Remarks

The results obtained within the framework of our investigations focused on reconstructing the morphological conditions and environmental evolution of the broader area surrounding the PMZ archaeological site and providing quite innovative and important information that goes well beyond, in both space and time, the initial target. They indeed contribute to unravelling the major hydrographic transformations that affected Thessaly during the latest Quaternary, allowing us to explain a major morphological anomaly in its central sector. In particular, we present and discuss evidence that the reach of the Peneios River presently flowing along the Peneiada Valley is very recent, certainly younger than the LGM period (c. 26.5–19.5ka BP) and possibly only definitively formed during the late Holocene. In this regard, on the basis of a systematic geophysical survey consisting of numerous horizontal to vertical spectral ratio (HVSr) measurements, Ambra Mantovani et al. have thoroughly documented that the bedrock underlying the recent loose deposits infilling the Peneiada Valley clearly deepens from ENE (Koutsochero area) towards the west (Zarko and Farkadona sector), where it reaches an estimated depth of about 150m from the surface (Fig. II.1.3).⁷⁴ A careful inspection and analysis of the entire Thessalian hydrographic network strongly suggest that in the past the Peneiada Valley represented the lower reach of the Titarissios River (Fig. II.1.6a), draining its waters into the western Thessalian ‘lowland’, at that time probably representing a wide lacustrine-to-marshy area (the so-called Karditsa Lake) fed by several independent hydrographic basins draining the Antichasia, Pindos and Othrys mountain ranges (Fig. II.1.5).

As a consequence of the tectonic activity that started generating the Tyrnavos and Larissa faults during the Late Pleistocene, the Titarissios River was diverted towards the eastern Thessalian Basin (Larissa area/lake), thus causing the abandonment of the Peneiada Valley, where only local deposition sourced from the valley flanks remained active (Fig. II.1.6b). On the other hand, due to the endorheic conditions characterising the western ‘lowland’, the Karditsa Lake was progressively infilled by fluvio-lacustrine deposits. The infilling process was highly asymmetric because the several internal deltas prograding from the western and the southern rivers were gradually merging towards the exit of the abandoned Peneiada Valley (i.e. the Farkadona area; Fig. II.1.7). Over time, this sedimentary process steadily reduced the size of the permanent water table, progressively shifting/delimiting the lacustrine area northeastwards.

Sometime after the LGM and likely during Holocene times, genuine fluvial-alluvial conditions reached the Peneiada Valley, thereby rapidly completing its infilling due to the locally and temporarily increased sedimentation rate as a consequence of the strongly reduced alluvial surface. The contextual aggradation and eastward progradation of internal deltas and the consequent development of a topographic gradient sloping eastwards (i.e. from Farkadona towards Koutsochero) ultimately allowed the altimetric threshold of the Kalamaki Gorge to be reached, there triggering an accelerated vertical entrenching from the gorge upstream. Once a permanent connection between the two major plains (Karditsa and Larissa) had been established, any major evidence of the western lake disappeared, leaving only local and temporary marshy areas, still marked in many historical geographic maps.⁷⁵

⁷⁴ Mantovani et al. 2018.

⁷⁵ Heuzey – Daumet 1876; Nobile 1910; Royal Hellenic Map Service 1909a; Royal Hellenic Map Service 1909b; Ministry of Agriculture 1928; Hellenic Army Geographical Service 2008.

It was in this rapidly changing geography and environmental conditions that Neolithic people lived, while some repercussions were probably still observed during antiquity and were handed down as a myth.