23 OSTRACOD CONTRIBUTION TO THE PALAEOENVIRONMENTAL STUDY OF KYPARISSIA 4 (MEGALOPOLIS BASIN, GREECE)

Penelope Papadopoulou[1,*], Maria Tsoni[1], George E. Konidaris[2], Vangelis Tourloukis[2,3], Eleni Panagopoulou[4], Panagiotis Karkanas[5], Katerina Harvati[2], George Iliopoulos[1]

[1]*Laboratory of Palaeontology and Stratigraphy, Department of Geology, University of Patras, Rio Patras, Greece*
[2]*Paleoanthropology, Institute for Archaeological Sciences and Senckenberg Centre for Human Evolution and Palaeoenvironment, Department of Geosciences, Eberhard Karls University of Tübingen, Tübingen, Germany*
[3]*Department of History and Archaeology, School of Philosophy, University of Ioannina, Ioannina, Greece*
[4]*Hellenic Ministry of Culture, Ephorate of Palaeoanthropology–Speleology, Athens, Greece*
[5]*M.H. Wiener Laboratory for Archaeological Science, American School of Classical Studies at Athens, Athens, Greece*
**penelpapadop@upatras.gr*

http://dx.doi.org/10.15496/publikation-97593

Keywords: ostracods; Kyparissia 4; Marathousa 1; Pleistocene; Greece

23.1 INTRODUCTION

The Megalopolis Basin, situated on the central part of Peloponnese in southern Greece, is an intramontane half-graben basin, which was formed during the Pliocene and is nowadays one of the largest coal mining districts in Greece. During the Pleistocene, lacustrine and fluvial sediments were deposited, including the lignite-bearing Marathousa Member of the Choremi Formation (Vinken, 1965). The sedimentary sequence of the Marathousa member has a total thickness of ~150 m at the center of the basin, and includes alternations between clastic sediments (clay, silt and sand) and 5–30 m thick dark brown lignite seams, intercalated with thin clastic layers (van Vugt et al., 2000 and references therein).

Previous paleoenvironmental research based on ostracods focused on the Middle Pleistocene (Lower Palaeolithic) site of Marathousa 1 (MAR-1; Fig. 1a), located between the Lignites II and III of the Marathousa Member, and dated to 500–400 ka (see Harvati et al., 2018, Panagopoulou et al., 2018 and references therein; Bludau et al., 2021). In this study, we present new paleoenvironmental evidence from lower stratigraphic horizons of the Marathousa Member, based on the ostracod record from the site Kyparissia 4 (KYP-4). KYP-4, located in the Kyparissia mine (Fig. 1a), was discovered in 2007 and has yielded a rich assemblage of large mammals, including hippopotamuses, elephants and deer (Athanassiou, 2018; Athanassiou et al., 2018). The site was recently revisited during a targeted field survey in the framework of the Megalopolis Paleoenvironmental Project (MegaPal). Besides the collection of additional large mammal

P. Papadopoulou: https://orcid.org/0000-0001-8442-4115
M. Tsoni: https://orcid.org/0000-0002-1719-7634
G. E. Konidaris: https://orcid.org/0000-0002-7041-233X
V. Tourloukis: https://orcid.org/0000-0002-9527-2708
E. Panagopoulou: https://orcid.org/0000-0002-4268-6157
P. Karkanas: https://orcid.org/0000-0002-7156-671X
K. Harvati: https://orcid.org/0000-0001-5998-4794
G.Iliopoulos: https://orcid.org/0000-0002-4875-128X

fossils (Athanassiou et al., this volume; Konidaris et al., this volume), sampling for molluscs (Boni et al., this volume), micromammals (van Kolfschoten et al., this volume) and ostracods (present study) also took place. Preliminary stratigraphic and biochronological data indicate that KYP-4 is older than MAR-1, and is dated close to the lower part of the Middle Pleistocene (Athanassiou, 2018; this volume; Karkanas et al., this volume; van Kolfschoten et al., this volume). The KYP-4 sedimentary sequence has a thickness of ~4.50 m and is divided into several distinct stratigraphic units, comprised by alterations of dark grey organic rich mud layers with an intercalation of a relatively thin lignite layer (Fig. 1b).

Ostracods are one of the most frequent microfossils found in archaeological and paleontological excavations, due to their existence in a wide variety of paleoenvironments (Mazzini et al., 2015). Especially in freshwater settings, where other microfossil groups such as foraminifera, are lacking, ostracods can provide extremely detailed information about the paleoenvironment and the paleoclimate. For this reason, ostracods in the last 20 years have become a fundamental addition to multidisciplinary archaeological and paleoanthropological research (Mazzini et al., 2015). In the present study, ostracod analysis is conducted in samples deriving from different layers of KYP-4 (Fig. 1b), aiming at the paleoenvironmental reconstruction of the studied section.

23.2 MATERIALS AND METHODS

Seven sediment samples were analyzed for ostracods originating from KYP-4 Area A (the main find-bearing area; Fig. 1). 1000 g of dry sediment was treated with 10% H2O2 until reaction stopped (3 to 24 hours, depending on the sample). The residues were washed through a 2 mm and 125 μm sieve using distilled water and further dried overnight at 50°C. All ostracod valves were extracted under OPTIKA stereoscopes. Ostracods were photographed digitally with OPTICAM BS 5 Mpx stereoscope camera. Identification, ecology and distribution information of ostracod species were derived mainly from Meisch (2000), Fuhr-

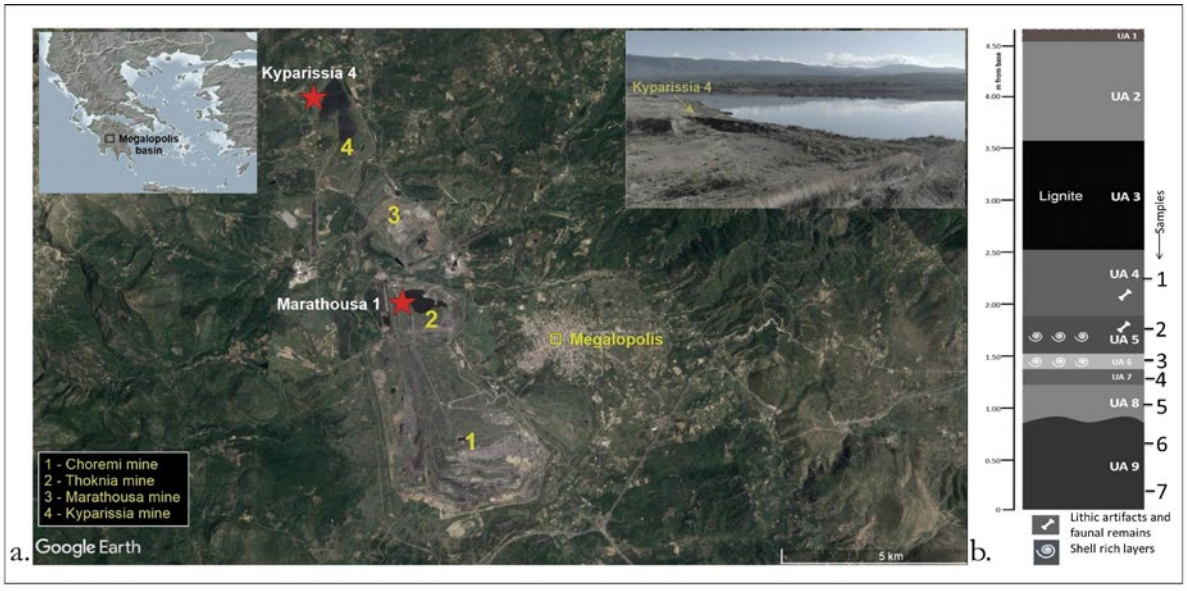

Figure 1: a, Upper left corner: geographic position of the Megalopolis Basin; center: geographic position of Kyparissia 4 and Marathousa 1 in relation to the main lignite mines of the Megalopolis Basin (satellite image from Google Earth); upper right corner: distant view of Kyparissia 4. b, simplified stratigraphic column of KYP-4 (Area A) showing the stratigraphic units and the position of the samples taken for the ostracod analysis.

mann (2012), several papers on the Stereo Atlas of Ostracod Shells (Athersuch, 1976), and other available published literature. Taphonomic indices were calculated (wherever possible) and interpreted after Schellenberg (2007) with: a) The adult to juvenile ratio (A/J) as an indirect indication for the energy of the environment. Values between 0.125–0.25 are typical for in situ death assemblages. Higher values reflect in situ death assemblages with taphonomic removal of juveniles. Significantly lower values could reflect transported juvenile valves or a mass death event (Belis et al., 1997; Schellenberg, 2007). b) The right valve/left valve ratio (RV/LV) for merely the same reason (Breman, 1980). Values significantly different from one (1) imply transportation of juvenile valves.

23.3 RESULTS AND DISCUSSION

Six out of the seven sediment samples (samples 2–7; stratigraphic units UA5–UA9) were barren of ostracods and/or contained either complete or broken molluscs, while in sample 4 (UA7), terrestrial microvertebrate bone fragments were found (Table 1). Nonetheless, a relatively rich ostracod taphocoenosis was extracted from sample 1 (UA4; 63 ostracod valves). UA4 is a crudely laminated

	Cyclocypris cf. *ovum*						*Potamocypris zschokkei*						*Fabaeformiscandona breuili*								*Candona* spp. (juveniles)						
Samples	Juveniles-Immature			Adults			Juveniles-Immature			Adults			Juveniles-Immature			Adults			A/J	RV/LV	Juveniles-Immature			%Art	RV/LV	Bone fragments (Arvicolidae)	Fragments (molluscs+ostracodes)
	LV	RV	C	LV	RV	C	LV	RV	C	LV	RV	C	LV	RV	C	LV	RV	C			LV	RV	C				
8																											
7																											
6																											
5																											
4																										*	
3																											
2																											
1		1						2			1		1			4	6		10	1,50	30	17	1		0,57		*

LV=Left valve, RV=Right valve, C=Carapace

A/J=Adult/Juvenile

C/V=Carapace/Valve

RV/LV=Right valve/Left valve

Table 1: Ostracod analysis results and taphonomy.

dark organic-rich mud with few sand clasts deposited in a low energy depositional environment. Ostracods thrive in hydrological regimes with low and moderate flow discharge but cannot withstand higher rates (Roca and Baltanas, 1993). Thus, the lack of ostracods in the other six samples could be connected to higher flow discharge.

In sample 1 (UA4), three ostracod taxa were identified down to the species level, while valves of juvenile stages were also picked (Fig. 2). Most of the identified ostracod valves (76%) belong to juvenile stages of Candoninae. However, the RV/LV ratio bears a value of 0.57, which indicates that some of them or all of them were transported from nearby freshwater environments.

Valves of the species *Fabaeformiscandona breuili* (Paris, 1920) account for 17% of the ostracod assemblage. It is a widespread species throughout central and southern Europe, present from Pleistocene to recent. It is a predominantly stygobiotic species, but it can also survive in surface environments always connected to underground waters (springs, waters flowing from springs, caves, etc.) (Meisch, 2000). As a fossil, it has been found mostly in interglacial conditions and/or in transitional conditions between the glacials-interglacials of central Germany (Fuhrmann, 2012). Only adult valves of this species were found (A/J ratio = 10), an indication of an *in situ* death assemblage with high taphonomic removal of juveniles. Relatively high transportation rates are also implied from the RV/LV ratio for the same species (RV/LV = 1.5).

Potamocypris zschokkei (Kaufmann, 1900) (5%) and *Cyclocypris* cf. *ovum* (2%) complete the taphocoenosis. *Potamocypris zschokkei* is widespread throughout Europe since the Pleistocene and it has been reported from interglacial and late glacial deposits (Fuhrmann, 2012). It is mostly found in muddy streams flowing from springs and, to a lesser extent, in stagnant waters of spring ponds (Meisch, 2000). *Cyclocypris ovum* (Jurine, 1820) prefers cool permanent water bodies, but it can survive in a wide variety of aquatic environments. Nevertheless, it seems to be reduced in high summer water temperatures and high precipitation rates (Fuhrmann, 2012). The number of valves of both species was not enough for the calculation of taphonomic indices. Actually, the *C.* cf. *ovum* valve corresponds to a juvenile individual and for this reason its identification to the species level is not ascertained. However, regarding their preservation condition (fragmentation, color, etc.), the valves of *Potamocypris zschokkei* and *Cyclocypris* cf. *ovum* do not show signs of significant transportation and were probably deposited *in situ*. It is worth noting

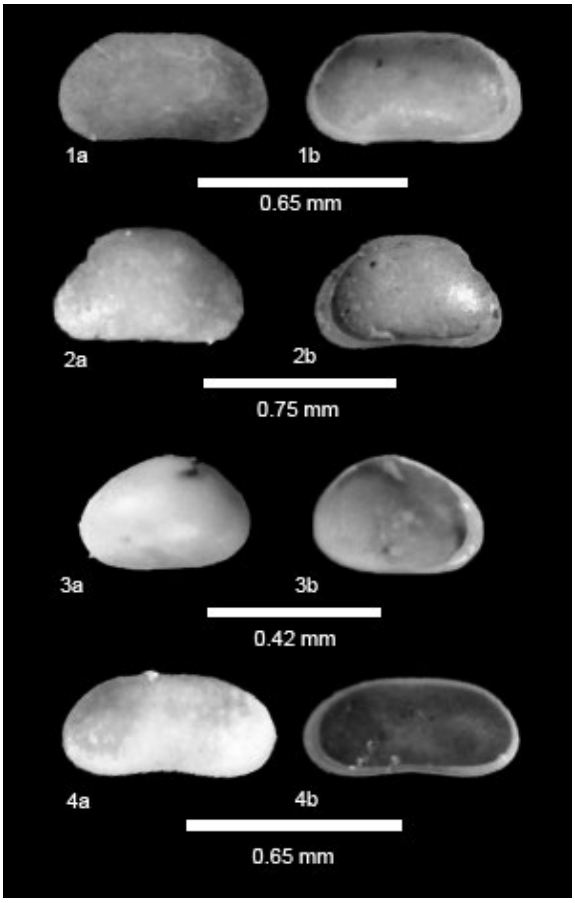

Figure 2: Digital photos of the identified ostracod taxa. 1. *Fabaeformiscandona breuili* a) left valve, external, b) left valve, internal; 2. *Potamocypris zschokkei* a) right valve, external, b) right valve internal; 3. *Cyclocypris* cf. *ovum* a) right valve, external, immature, b) right valve, internal, immature; 4. *Candona* a) right valve, external, juvenile b) right valve, internal, juvenile.

that nowadays *P. zschokkei* in combination with *C. ovum* are found in Pyrenean Bi-carbonate springs (connected to limestone basement) with relatively low temperatures (possibly lower than 15°C), low mineralization and wet climate (Mezquita et al., 1999). A significant number of widely distributed cold-water stenothermal species occurs in that area (a transitional area between northern/central European and Mediterranean regions), implying that those habitats acted as refugia for widely distributed species during the glacials (Mezquita et al., 1999), which could also be the case for the Middle Pleistocene Megalopolis Basin.

The number of species in the respective sample is apparently low which points towards stressed environmental conditions. Due to the identified species' ecological preferences, the connection of the depositional environment to a cool carbonate spring is indisputable. The limestone basement (belonging to the Pindos geotectonic zone) of the studied area is in good agreement with the inferred paleoecological data. The low number of individuals can be attributed to the low stability of the springs (Mezquita et al., 1999) or more likely to a less favorable depositional environment such as a stream flowing from the spring. This is further supported by the high transportation rates of Candoninae, implied by the respective taphonomic indices. The ostracod assemblages of such environments are not well studied, probably due to the high diversity of microhabitats.

The coexistence of *P. zschokkei* and *C. ovum* points towards a wet climate with no extreme summer temperatures. Because of the extremely low number of individuals, this paleoclimate estimation must be applied with caution. Moreover, both *F. breuili* and *P. zschokkei* are commonly found in interglacial and/or transitional stages of central Europe. Therefore, the climatic conditions during the deposition of the respective layer should have resembled those that prevailed in regions further north, during interglacial or/and transitional stages.

Samples with high numbers of juvenile Candoninae have also been noticed at MAR-1 (stratigraphic units UA2 and UA3 of Area A, and UB3 and UB4 of Area B; Bludau et al., 2021). At this site, *P. zschokkei* was also observed in low frequencies (samples from UB3 and UB7). However, some samples from MAR-1 (UA2, UA3, UB3, UB4) contained also several representatives of *Ilyocypris* spp. The paleoenvironment of MAR-1 was also interpreted as deposition in streams or ponds deriving from springs' water. However, in the sample UA4 of KYP-4, *Ilyocypris* spp. are totally absent. This can possibly be attributed to slightly higher water temperature and/or higher range difference between summer and winter temperatures at MAR-1 (Roca and Baltanas, 1993). It is worth mentioning that in the study of Lüttig (1968) on the ostracods of Megalopolis Basin, none of the identified species at KYP-4 have been mentioned, while *Fabaeformiscandona breuili* is not recorded either at MAR-1, thus it is reported for the first time from the Megalopolis Basin herein.

23.4 CONCLUSIONS

In this work, ostracod analysis shed light on the paleoenvironmental conditions that prevailed during the deposition of organic rich mud layers at the early Middle Pleistocene site of KYP-4. The different layers of the studied section must have been deposited under fluctuating flow discharge rates. The sample from the stratigraphic unit UA4 (the main lithic/vertebrate-bearing layer) was deposited in a slow to moderate flowing stream fed by a cool (constantly lower than 15 °C) carbonate spring. Even if the data presented herein are restricted, they are possibly indicative of a wet climate with relatively stable temperatures throughout the year.

The climatic conditions during the deposition of this layer could resemble the interglacial or transitional conditions of central Europe. More research is needed in order to confirm these climatic conditions.

ACKNOWLEDGMENTS

Field survey in the Megalopolis Basin was conducted in the framework of the Megalopolis Paleoenvironmental Project (MegaPal) under a permit granted to the Ephorate of Paleoanthropology–Speleology, Hellenic Ministry of Culture, and the American School of Classical Studies at Athens. Fieldwork was supported by the ERC Consolidator Grant ERC-CoG-724703 ("CROSSROADS") awarded to K.H. G.E.K., V.T. and K.H. are also supported by the Deutsche Forschungsgemeinschaft (DFG Project no. 463225251, "MEGALOPOLIS"). K.H. is also supported by the ERC Advanced Grant ERC-AdG-101019659 ("FIRSTSTEPS"). We thank A. Junginger and one anonymous reviewer for their constructive comments and suggestions.

REFERENCES

Athanassiou, A., 2018. Pleistocene vertebrates from the Kyparíssia lignite mine, Megalopolis Basin, S. Greece: Rodentia, Carnivora, Proboscidea, Perissodactyla, Ruminantia. Quaternary International, 497, pp. 198–221.

Athanassiou, A., Michailidis, D., Vlachos, E., Tourloukis, V., Thompson, N. and Harvati, K., 2018. Pleistocene vertebrates from the Kyparíssia lignite mine, Megalopolis Basin, S. Greece: Testudines, Aves, Suiformes. Quaternary International, 497, pp. 178–197.

Athanassiou, A., Konidaris, G.E., Tourloukis, V., Thompson, N., Giusti, D., Karkanas, P. and Harvati, K., this volume. The Middle Pleistocene large mammal fauna from Kyparissia (Peloponnese, S. Greece): New collected material.

Athersuch J., 1976. Stereo-Atlas Ostracod Shells, 3(21), pp. 117–124.

Belis, C. A., 1997. Palaeoenvironmental reconstruction of Lago di Albano (Central Italy) during the Late Pleistocene using fossil ostracod assemblages. Water, Air, and Soil Pollution, 99, pp. 593–600.

Bludau, I.J.E., Papadopoulou, P., Iliopoulos, G., Weiss, M., Schnabel, E., Thompson, N., Tourloukis, V., Zachow, C., Kyrikou, S., Konidaris, G.E., Karkanas, P., Panagopoulou, E., Harvati, K. and Junginger, A., 2021. Lake-level changes and their paleoclimatic implications at the MIS12 Lower Paleolithic (Middle Pleistocene) site Marathousa 1, Greece. Frontiers in Earth Science, 9, 668445.

Boni, G., Syrides, G., Konidaris, G.E., Athanassiou, A., Tourloukis, V., Koukousioura, O., Panagopoulou, E., Karkanas, P. and Harvati, K., this volume. Preliminary results on the taxonomy and paleoenvironmental analysis of the mollusc fauna from Marathousa 1, Marathousa 2 and Kyparissia 4 (Middle Pleistocene, Megalopolis Basin, Greece).

Breman, E., 1980, Differential distribution of left and right ostracode valves in the Adriatic Sea. Palaeogeography, Palaeoclimatology, Palaeoecology, 32, pp. 135–141.

Fuhrmann, R., 2012. Atlas quartärer und rezenter Ostrakoden Mitteldeutschlands. Naturkundliches Museum Mauritianum, Altenburg.

Harvati, K., Konidaris, G. and Tourloukis, V., 2018. The Gates of Europe. Quaternary International, 497, pp. 1–240.

Karkanas, P., Tourloukis, V., Thompson, N., Giusti, D., Tsartsidou, G., Athanassiou, A., Konidaris, G., Roditi, E., Panagopoulou, E. and Harvati, K., this volume. The Megalopolis

Paleoenvironmental Project (MegaPal).

Konidaris, G.E., Athanassiou, A., Panagopoulou, E., Karkanas, P. and Harvati, K., this volume. Fossil macaques (Cercopithecidae, Primates) from the Middle Pleistocene of the Megalopolis Basin (Greece) with description of a new specimen from Kyparissia 4.

Lüttig, G., 1968. Die Ostrakoden des Megalopolis-Beckens (Peloponnes) und die Grenze Tertiär/Quartär. Giornale di Geologia, 35, pp. 73–82.

Mazzini, I., Goiran, J.P. and Carbonel, P., 2015. Ostracodological studies in archaeological settings: a review. Journal of Archaeological Science, 54, pp. 325–328.

Meisch, C., 2000. Freshwater Ostracoda of Western and Central Europe. Spektrum Akademischer Verlag, Heidelberg

Mezquita, F., Tapia, G. and Roca, J.R., 1999. Ostracoda from springs on the eastern Iberian Peninsula: ecology, biogeography and palaeolimnological implications. Palaeogeography, Palaeoclimatology, Palaeoecology, 148(1–3), pp. 65–85.

Panagopoulou, E., Tourloukis, V., Thompson, N., Konidaris, G., Athanassiou, A., Giusti, D., Tsartsidou, G., Karkanas, P. and Harvati, K., 2018. The Lower Palaeolithic site of Marathousa 1, Megalopolis, Greece: Overview of the evidence. Quaternary International, 497, pp. 33–46.

Roca, R.J., Baltanas, A., 1993. Ecology and distribution of Ostracoda in Pyrenean springs. Journal of Crustacean Biology, 13(1), pp. 165–174.

Schellenberg, S.A., 2007. Marine ostracods, in: Elias, S.A. (Ed.), Encyclopedia of Quaternary science. Elsevier, Amsterdam, pp. 2046–2062.

van Kolfschoten, T., Konidaris, G.E., Doukas, C., Athanassiou, A., Tourloukis, V., Panagopoulou, E., Karkanas, P. and Harvati, K., this volume. Voles (Rodentia, Mammalia) as a proxy to date the site Kyparissia 4 (Megalopolis Basin, Greece).

Van Vugt, N., de Bruijn, H., van Kolfschoten, T. and Langereis, C.G., 2000. Magneto- and cyclostratigraphy and mammal-fauna's of the Pleistocene lacustrine Megalopolis Basin, Peloponnesos, Greece. Geologica Ultrajectina, 189, pp. 69–92.

Vinken, R., 1965. Stratigraphie und Tektonik des Beckens von Megalopolis (Peloponnes, Griechenland). Geologisches Jahrbuch, 83, pp. 97–148.