17 OVERVIEW OF MAR18-1A AND MAR18-2A DRILL CORE ANALYSIS AND CHRONOLOGICAL FRAMEWORK

Ines J. E. Bludau[1,2]*, Annett Junginger[1,2]*, Bernd Wagner[3], Uwe Kirscher[1], Charlotte Zachow[1], Maria Schindler[1], Vangelis Tourloukis[1,4,5], Styliani Kyrikou[1,4], Panagiotis Karkanas[6], Eleni Panagopoulou[7], Katerina Harvati[1,2,4,8]

[1]*Department of Geosciences, Eberhard Karls University of Tübingen, Tübingen, Germany*
[2]*Senckenberg Centre for Human Evolution and Palaeoenvironment, Tübingen, Germany*
[3]*Institute of Geology and Mineralogy, University of Cologne, Cologne, Germany*
[4]*Paleoanthropology, Institute for Archaeological Sciences, Eberhard Karls University of Tübingen, Tübingen, Germany*
[5]*Department of History and Archaeology, School of Philosophy, University of Ioannina, Ioannina, Greece*
[6]*M.H. Wiener Laboratory for Archaeological Science, American School of Classical Studies at Athens, Athens, Greece*
[7]*Hellenic Ministry of Culture, Ephorate of Palaeoanthropology-Speleology, Athens, Greece*
[8]*DFG Centre for Advanced Studies 'Words, Bones, Genes, Tools', Eberhard Karls University of Tübingen, Tübingen, Germany*
**ines.bludau@uni-tuebingen.de, annett.junginger@uni-tuebingen.de*

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17.1 INTRODUCTION

Greece, with its position between continental Europe, Africa and Asia, is an important crossroad for the hominin migration into Europe (e.g., Harvati et al., 2009; Tourloukis and Karkanas, 2012; Harvati, 2016; Harvati et al., 2018). Its significance as a glacial refuge or simply as a transit region is still heavily debated due to the scarcity of archaeological evidence from the Paleolithic (Agustí et al., 2009; Harvati, 2016; Muttoni et al., 2013; Reyes-Centeno et al., 2017; Stewart and Stringer, 2012; Tsakanikou et al., 2021). The archaeological site Marathousa (MAR-1), located in the Megalopolis Basin on the central Peloponnese, is one of only four Lower Paleolithic sites identified in the country until recently (Tourloukis and Harvati, 2018). Its preservation and chronological framework are optimal for investigating the significance of the region as a glacial refugium or simply a transit region. The Megalopolis Basin consists mainly of lignite-bearing fluvio-lacustrine sediments. The basin filling was drilled and cored in 2018, retrieving two complete cores (MAR18-1A and MAR18-2A) and first results are presented here.

Preceding studies of the archaeological site MAR-1 revealed sediments indicative of a paleo-lake shoreline environment. The sediments contain various fossils (e.g., mammalian bones, seeds, leaves and wood pieces), as well as lithic tools, indicating hominin activities (Field et al., 2018; Konidaris et al., 2018; Tourloukis et al.,

I. Bludau: https://orcid.org/0000-0002-0876-9012
A. Junginger: https://orcid.org/0000-0003-3486-0888
B. Wagner: https://orcid.org/0000-0002-1369-7893
U. Kirscher: https://orcid.org/0000-0003-4203-1430
Ch. Zachow: https://orcid.org/0009-0006-4735-4131
V. Tourloukis: https://orcid.org/0000-0002-9527-2708
S. Kyrikou: https://orcid.org/0009-0000-8199-1317
P. Karkanas: https://orcid.org/0000-0002-7156-671X
K. Harvati: https://orcid.org/0000-0001-5998-4794
E. Panagopoulou: https://orcid.org/0000-0002-4268-6157

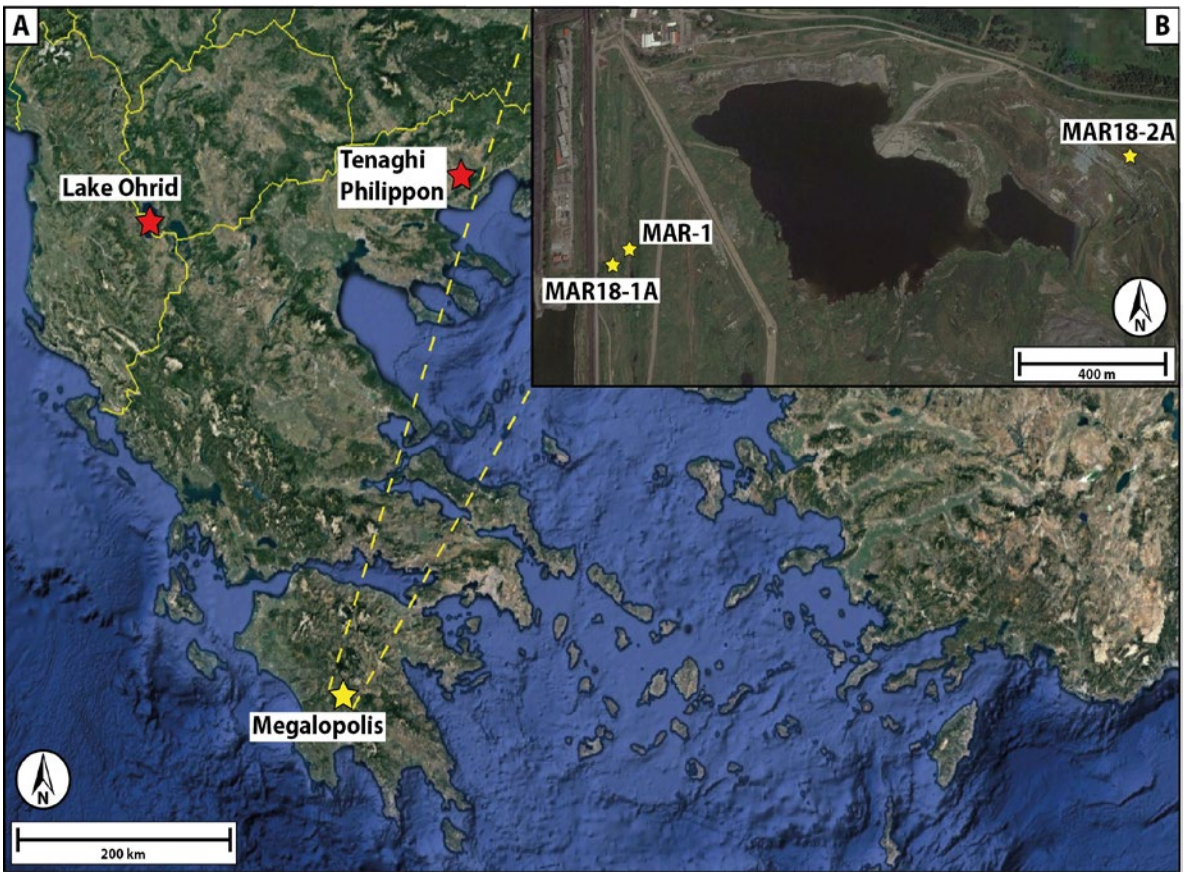

Figure 1: A) Overview of the drill location (yellow star) on the Peloponnese peninsula and sites (red stars) mentioned in the text. B) Drill locations of MAR18-1A and MAR18-2A (Google Earth image).

2018b). Remarkable is a large assortment of lithic tools in spatial and stratigraphic association with the bones of a straight-tusked elephant *Palaeoloxodon antiquus* that show cut marks, being evidence for butchering activities of hominins (Konidaris et al., 2018; Tourloukis et al., 2018b). MAR-1 was dated to ~450 ka, corresponding with Marine Isotope Stage (MIS) 12. Paleoenvironmental reconstructions conducted at the 6-m profile of MAR-1 revealed the presence of seasonal ponds and the potential of the basin as a refuge for hominins and other animals during the tentatively harsh, glacial climate conditions (Bludau et al., 2021; Tourloukis et al., 2018a).

The 6-m long sedimentary succession of MAR-1 is part of the ca. 135 m thick Marathousa Member, deposited during the Pleistocene (Van Vugt et al., 2001). The sediment succession is characterized by alternating layers of clastics (clays, sands and silts) and lignites (Vinken, 1965) and covers the period ~800–400 ka (Tourloukis et al., 2018a; van Vugt et al., 2001). Over the past years, additional archaeological localities within the Marathousa Member have been identified (Konidaris et al., 2023; Karkanas et al., this volume). In order to provide a temporally well-constrained paleoenvironmental framework, two sediment cores, MAR18-1A and MAR18-2A, have been drilled through the entire Marathousa Member in 2018 (Figs. 1; 2). Here, an overview of the ongoing analysis is presented. The deposition of the cored sediments occurred during the middle and end phase of the Early-Middle Pleistocene Transition (EMPT), with the Brunhes-Matuyama Boundary (B-M Boundary, 780 ka) located at ~83 m core depth in MAR18-1A (Fig. 2; see preliminary re-

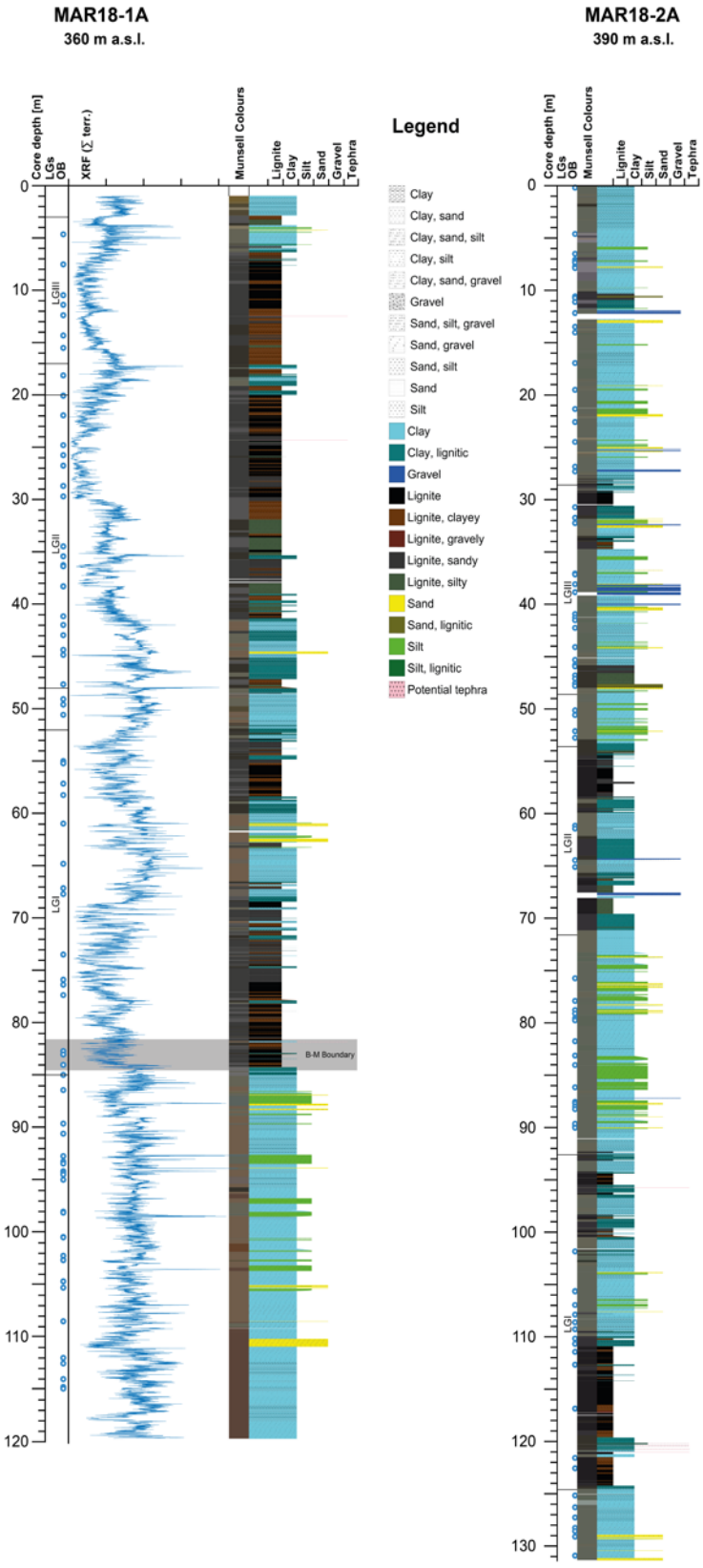

Figure 2: Stratigraphy of cores MAR18-1A and MAR18-2A with first µ-XRF results showing the sum of terrestrial elements (Al, Fe, K, Rb, Si, Ti), as well as the inferred depth of the Brunhes-Matuyama Boundary (B-M Boundary).

sults) and with MAR-1, representing ~450 ka, at ~15–17 m core depth. The EMPT is a major global climate transition from ~41 ka to ~100 ka glacial-interglacial periodicity, which lasted in total from 1.4 to 0.4 Ma, ending with the Mid-Brunhes Event (Head and Gibbard, 2015). Besides the scarcity of terrestrial proxy-records in the Mediterranean realm covering large parts of the EMPT, these cores, together with the number of new archaeological sites in the basin, bear a high potential for understanding how environmental changes may have influenced the behavior of hominins in Greece over time.

17.2 DATA AND METHODS

Two sediment cores were retrieved in 2018, MAR18-1A (N 37.408387°, E 22.090907°) ~20 m north to the archeological site MAR-1, and MAR18-2A (N 37.410291°, E 22.108264°) located 1.5 km east of MAR-1 (Fig. 1) with a drill depth of 103 m and 123 m, respectively. In 2019, additional outcrop descriptions at the MAR18-2A site have been conducted (MAR19-2AP) in order to correlate the lithologies with the drill cores. The drilling was carried out without liners due to the high abundance of lignites, with each drill run being 3 m. The cores were cut into 1 m long sections and stored in wooden boxes for transport. In the laboratory, the cores were transferred into plastic liners and cut into two halves lengthwise, with an archive half for non-destructive analyses, and a working half for destructive analyses. After core opening, a detailed core description was performed, followed by non-destructive μ-XRF core analysis at the Geoscience department at Cologne University. Core logging was performed using the Corelyzer and Psicat software.

The core analysis is complemented by ongoing grain-size analysis, CNS, TOC, micro-tephra, as well as paleomagnetic measurements. In order to provide an age model for the drilled cores, different age modelling approaches are currently tested for their robustness focusing on the uppermost 87 m of the MAR18-1A core. The study utilizes and compares three different age modelling approaches: a) a classical statistical model with a static bandpass filter (Duesing et al., 2021; Grant et al., 2017; Hays et al., 1976); b) the multiband wavelet model (MUBAWA) with adaptive bandpass filters (Duesing et al., 2021), both tuning the dataset to orbital parameters; c) a hiatus model that constructs an age model based on dating and statistical properties of the sediments and their depositional behavior (Trauth, 2014). At 87 m depth, a drastic shift in sedimentology pattern (dark lignites and clays to grey and brown clays) indicates the presence of a considerable hiatus. Consequently, the study is restricted to the uppermost 87 m. The hiatus occurs just below the approximate depth of the B-M Boundary, which is tentatively at ~83 m, and is considered to indicate that either the Early Pleistocene or the Pliocene sediments (clays, sands and gravels) of the underlying Trilofon Formation have been reached.

17.3 PRELIMINARY RESULTS

17.3.1. STRATIGRAPHY AND μ-XRF

While the drilled core depths were 103 m (MAR18-1A) and 123 m (MAR18-2A), the described material encompasses ~119 m and ~131 m, respectively. The differences in lengths can be caused by the open-core-drilling technique, where clays can stretch and lignites expand, by gas (CH_4) expansion or sediment lengthening during core lifting from the borehole. Both cores consist of alternately deposited clastic material (clay, silt and sand) and lignites, with the occurrence of more clastic material in the lower parts (Fig. 2). Due to the irregular

Section	Section Depth	Core Depth	Tephra
MAR18-1A 08-1	0.57—0.58	13.06—13.07	—
MAR18-1A 12-1	0.10—0.11	25.15—25.16	+
MAR18-1A 12-2	0.08—0.09	26.00—26.01	+
MAR18-1A 12-2	0.15—0.16	26.07—26.08	+
MAR18-1A 12-3	0.05—0.06	27.03—27.04	+
MAR18-1A 13-4	0.34—0.35	31.20—31.21	—
MAR18-1A 14-2	0.18—0.19	32.00—32.01	—
MAR18-1A 22-3	0.70—0.71	51.55—51.56	—
MAR18-1A 26-2	0.24—0.25	62.51—62.52	—
MAR18-1A 26-2	0.49—0.50	62.76—62.77	—
MAR18-1A 26-2	0.58—0.59	62.85—62.86	—
MAR18-1A 26-2	0.86—0.87	63.13—63.14	—
MAR18-1A 29-4	0.08—0.09	72.80—72.81	—
MAR18-1A 29-4	0.25—0.26	72.97—72.98	—
MAR18-1A 29-4	0.40—0.41	73.12—73.13	—
MAR18-1A 29-4	0.50—0.51	73.22—73.23	—

Table 1: Overview of analyzed µ-tephra samples in core sections and with total core depth.

behavior of lignites and their different composition in general, lignite seams in the cores can only tentatively be assigned to the three (LGI/Elias, LGII/Otto, LGIII/Panagiotis) known lignite seams from outcrop observations. The correlations place LGI in MAR18-1A between depths ~87–52 m, LGII to ~48–20 m and LGIII to 17–3 m. Respective lignite seams are found in MAR18-2A core at ~124–92 m (LGI), ~71–53 m (LGII) and ~48–28 m (LGIII) depths.

Core Depth (m)	Age (ka)	Error (ka)	Method
12.95	415	46	Post-infrared infrared stimulated luminescence (Jacobs et al., 2018)
13.05	420	10	Age modelling (Tourloukis et al., 2018)
18.05	451	35	Post-infrared infrared stimulated luminescence (Jacobs et al., 2018)
19.45	457	40	Post-infrared infrared stimulated luminescence (Jacobs et al., 2018)
19.55	468	34	Post-infrared infrared stimulated luminescence (Jacobs et al., 2018)
20.00	480	10	Age modelling (Tourloukis et al., 2018)
83.00	780	10	Paleomagnetic measurements

Table 2: Overview of dating methods, ages and errors used in the age modelling.

An important change in MAR18-1A core lithology takes place at a depth of ~87 m (Fig. 2). Massive yellowish brown silty and sandy clays occasionally interrupted by olive-grey clays (below) sharply transition to black and grey lignites that are intercalated with layers of reddish, brown and grey clays, silts and sands (above). While iron oxide and carbonate nodules often appear in the clastic layers, their number is markedly higher in the lower part of the core. Shell fragments can often be found in the lignites and lignitic clays. Compared to MAR18-1A, MAR18-2A contains significantly less black and grey lignites and rather dark greenish-grey, as well as olive-grey, clastic material. The clastics comprise clays, silts and sands, and often contain iron and carbonate nodules. Shell fragments were encountered especially in the lower lignites and in some thin layers of the upper clastics. The differences in the thickness and sedimentology of the two cores are attributed to their location relative to the former lake. MAR18-1A is located at the western, shallower margin of the basin, where-

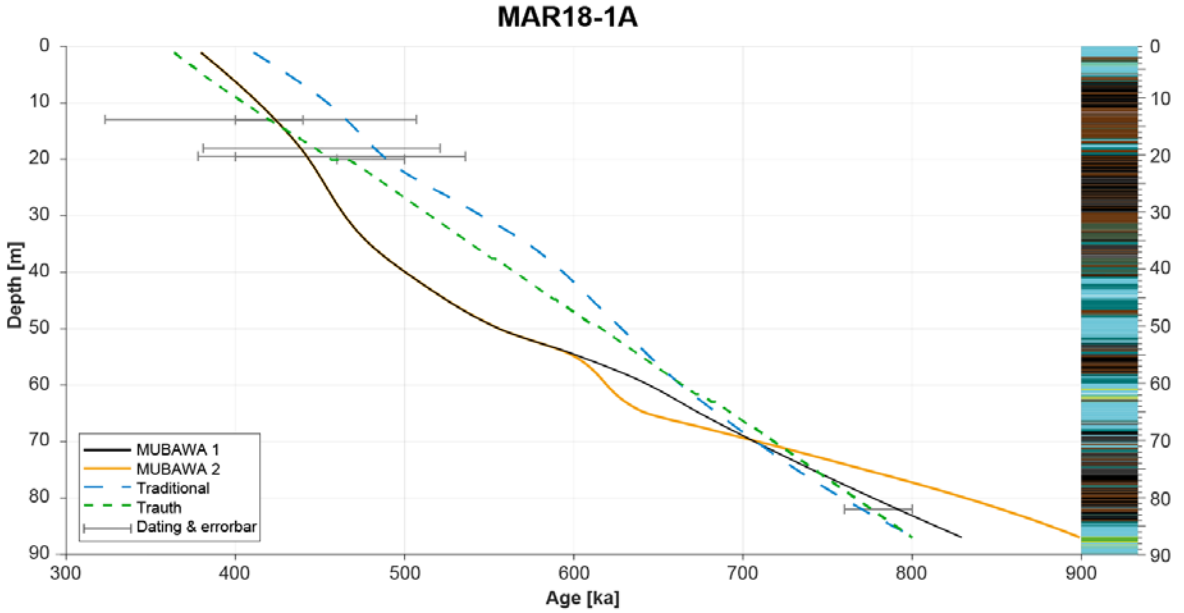

Figure 3: Summary of different age modelling approaches of core MAR18-1A with MUBAWA 1 being the preferred age model at this stage of the analysis.

as MAR18-2A is placed in the eastern, deeper part of the former lake (Vinken, 1965).

The µ-XRF analysis reveals high counts of terrestrial elements (e.g., Al, Ti, K, Fe, Rb, Si) typically observed in the clastic sediments, while low counts mirror the organic rich lignites.

17.3.2. CHRONOLOGY

The first results of the paleomagnetic analyses of MAR18-1A reveal the presence of the B-M Boundary located between ~81.5–84.5 m core depth. The tentative depth of the archaeological site MAR-1 sediments in the core MAR18-1A, that is dated to ~450 ka, most likely at 14–16 m core depth. Consequently, the sedimentary sequence between the lowermost and uppermost lignite seam in the core must encompass at least the time period between ~780–450 ka.

For micro-tephra analysis, horizons were selected where odd peaks in the in the µ-XRF record occurred. While tephra shards could be identified in several samples (Tab. 1), it was not enough for a more detailed analysis.

On the basis of the existing and preliminary ages (Tab. 2), the different age models (Trauth, Classic, MUBAWA) yield a rough general depositional time period of MAR18-1A between ~350–800 ka, ~410–800 ka and ~375–900 ka, respectively, with high internal depositional variations (Fig. 3). Of those, the age model generated with the MUBAWA code is considered the best fitting one. This highly statistical approach does not overly rely on input ages, it utilizes them only as control feature to evaluate the precision of various generated models, and compensates for post depositional diagenetic changes like compaction.

17.4 FUTURE PERSPECTIVE

The cores MAR18-1A and MAR18-2A are remarkable due to their length and continuity in sedimentation which is unparalleled in this region so far. Combining the results of the cores MAR18-1A and MAR18-2A with the two contemporaneous climate archives of Tenaghi Philippon (Tzedakis et al., 2006) and Lake Ohrid (Wagner et al., 2019), grants the opportunity to provide a region-

al paleo-climate gradient map of the EMPT and its potential impact on hominin migrations. The insights gained by performing a paleoenvironmental reconstruction from the cores using a multiproxy approach including pollen, biomarker, geochemistry and aquatic microfossils will help to identify why and when the Megalopolis Basin has served as a refuge region. Furthermore, potential forcing mechanisms that may have triggered hominin migrations could be identified, increasing the understanding of potential migration routes. Finally, it will be possible to clarify why hominins choose to settle in certain areas, which in turn might aid in identifying other archeological sites.

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