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RESEARCH ARTICLE

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A geoarchaeological study of the construction of the Laona tumulus at Palaepaphos, Cyprus

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Abstract

The tumulus of Palaepaphos-Laona is a monumental earthwork. Its size makes it unique in the landscape of ancient Cyprus, where even smaller burial mounds are extremely rare. It is characterized by a composite stratigraphic sequence and a wide range of carefully arranged construction materials. To reconstruct the building process, we employed a geoarchaeological approach, including a high-resolution microstratigraphic analysis. The study reveals a careful selection of construction materials and variability in the construction methods, reflecting a long tradition of building skills and empirical knowledge regarding the materials' engineering properties. It is evident that the tumulus of Laona was not a product of earth accumulation but an accomplished architectural structure. Several building stages were recorded, which along with repairs and intervals of exposure of the sediments, they represent temporal cycles of different nature and magnitude. As the height of the structure gradually increased, the tumulus became an imposing physical mark that gave the landscape a new meaning. Nevertheless, the memory of the ancestral testimony it was meant to convey to future generations was lost.

KEYWORDS
Cyprus, earthworks, geoarchaeology, soil micromorphology, tumulus construction

1 | INTRODUCTION

Tumuli are earth-constructed monuments. They permanently dominate the landscape for successive generations, carrying ancestral meanings and messages for later visitors and viewers (Papadopoulos, 2006). Although they have been described as 'a near-ubiquitous phenomenon' (Alcock, 2016, p. 2), artificial mounds are not known to have been employed as place-making artifacts in any period of Cyprus's cultural history. The absence of a tumuli culture in Cyprus makes the tumulus of Laona an extremely rare and unexpected monument (cf. Iacovou, 2017, p. 327–328). This, and the evidently complex structure of the monumental earthwork of Laona, motivated the authors to undertake the research presented here.

Traditionally, tumuli have been a focus of research for the architectural remains they contain. Emphasis is mostly placed on the built features included in them, that is, a tomb or other monument, and rarely on the earthwork part of the construction, which is often considered as a product of sediment accumulated into a pile. With the integration of multiscalar geoarchaeological analyses (Evstatiev et al., 2005; Gergova et al., 2005; Inomata et al., 2020; Kidder & Sherwood, 2017; Papadopoulos, 2006; Papadopoulos et al., 2007, 2008; Sherwood & Kidder, 2011; Sherwood et al., 2013; Syrides et al., 2017) it is now possible to view the tumuli as artifacts, and their construction as a cultural process aimed at creating a prominent landmark that transforms 'space into place' (cf. Papadopoulos, 2006, p. 83). Tumuli construction required deep knowledge of soil properties, purposeful selection of soils and sediments for their geotechnical characteristics, and a well-designed construction plan.

The multiscalar analysis adopted in relation to the tumulus of Laona incorporated (1) an excavation strategy designed to reveal the 3D geometry of the deposits, (2) field observations focusing on sedimentary structures, and (3) micromorphological analysis of sediments and potential source materials. The data were used to define the materials, techniques, and equipment of mound-building, evaluate the energy required, and decode the monument's construction stages and pace. Understanding how earthen mounds were constructed demonstrates that tumuli are accomplished architectural structures; it, also, provides an insight into the social, political, and economic organization of the societies that had them raised.

2 | THE SITE

2.1 | The geological setting

Laona was constructed on a Pleistocene alluvial fan (Zomeni, 2012, p. 238), (Figure 1); that is volcaniclastic sandstones, tuffs, pillow lavas, lava breccias, and Troodos ophiolites (Zomeni, 2012, p. 192). The fan is formed over Miocene marls. Red decalcified soils overlay the alluvial fan and calcareous soils cover the marly substrate. All the above formations constitute the source materials of the tumulus as described below.

2.2 | The archaeology of Iaona (2012–2019)

If one is visiting the sanctuary of Aphrodite in Palaepaphos and turns one's gaze eastward, toward the agricultural terraces that define the landscape beyond the Late Bronze Age temenos (cf. Maier, 2004, p. 39-45; Iacovou, 2019, figures 2 and 5), one is bound to see the hillock known locally as Laona (Figure 2).

In spite of its prominence, the locals of the village of Kouklia (originally called Couvoucle; cf. Maier, 2004, p. 28; Iacovou, 2014, p. 162, 168), which has grown on the plateau of the sanctuary since the Middle Ages, have no stories to tell concerning Laona; they have never thought of it as anything other than a natural hillock (Figure 3). In 2006, when the Palaepaphos Urban Landscape Project (hereon, PULP) was initiated (cf. Iacovou, 2008, 2013), the discovery of a tumulus did not feature in anyone's mind.

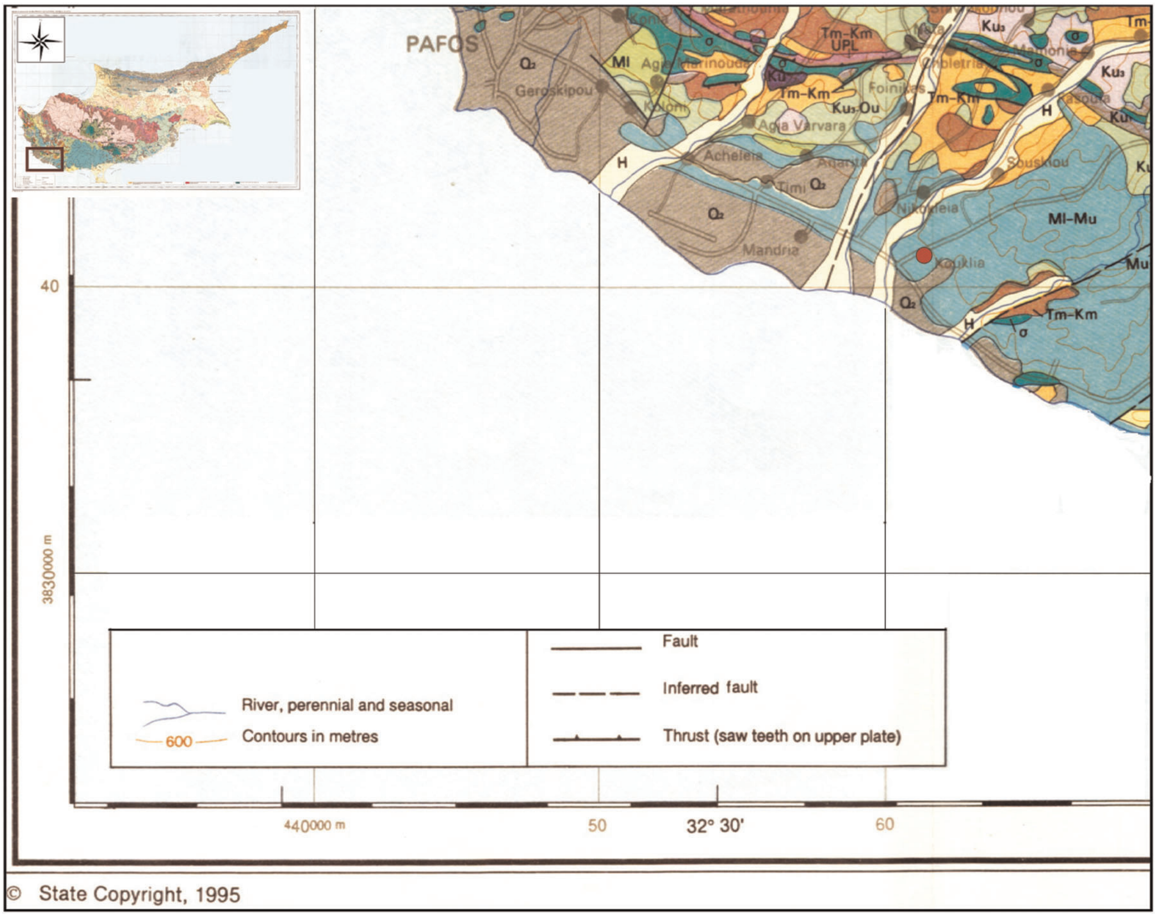

FIGURE 1 Location of the site on the geological map of Paphos (red dot). Data provided by the Geological Department of Cyprus. Mi-Mu/Mi: chalks, marls, calcarenites and limestones (Miocene), H: Alluvium (Holocene), Q2: Terrace deposits (Pleistocene), Tm-Km (yellow)/Tm-Km (brown): Lava, limestone breccias, and clastic sedimentary rocks (M. Cretaceous-M. Triassic), UPL: Upper Pillow Lavas (U. Cretaceous), Ku: amphibolite-grade metavolcanics and marbles (U. Cretaceous), Ku3-Qu: chalks, marls with cherts (Palaeogene), Ku3: Poorly sorted debrites, σ: Serpentinite (U. Cretaceous)

FIGURE 2 Laona in relation to the sanctuary of Aphrodite and the citadel of Hadjiabdoullah. Background: aerial orthophoto of Kouklia-Palaepaphos (2008); source: Department of Lands and Surveys, Cyprus. Drafted by A. Agapiou (PULP@)

Laona was identified as an anthropogenic mound by PULP's research associate Zomenia Zomeni (Geological Survey Department Senior Geological Officer) and Professor Jay Noller (Department of Crop and Soil Science, Oregon University). Its investigation began in 2012 in the context of PULP's annual fieldwork (https://ucy.ac.cy/pulp/). The first published report on Laona (Iacovou, 2017, in Greek) describes the process of its identification as an anthropogenic mound and the gradual development of a research and excavation plan before the geoarchaeological study, which was undertaken in 2017–2018. The mound is visible on air-photographs of which the earliest dates to around 1940; they have been collected and analyzed by PULP's research associate Athos Agapiou (2013, p. 156, pl. 18). Agapiou has also georeferenced the mound, which is located less than 100 m to the north of the terrace of Hadjiabdoullah, now firmly identified as the citadel of the local dynasties that ruled the

FIGURE 3 Laona in the landscape of Kouklia-Palaepaphos; view from the north (photo M. Iacovou)

FIGURE 4 Laona ground plan (above), indicating the excavation squares in the SE quarter of the mound and the position of micromorphological samples (red dots). Drafted by A. Agapiou (PULP@). Detail of ground plan (below) with the 'pseudo-grave', the position of the section on Figure 7 (indicated with a red line) and the position of the micromorphological samples (red dots)

FIGURE 5 Stratigraphy of the west section (north to south) of the tumulus (photo M. Iacovou)

city-state of ancient Paphos in the Cypro-Classical period (cf. Iacovou, 2019, p. 222–224: figure 18; Iacovou & Karnava, 2019).

To date, excavations have been conducted exclusively in the SE quarter of the tumulus (Figure 4), whose measurements have been estimated as 100 × 60 × 10 m. It has been decided that the northern half should be preserved untouched to convey the monumentality of this rare landscape marker. The natural hillock (close to 5.000 m^2) on which the tumulus was raised lies at 105 m asl (on the lower south side). A thick layer of marl covers the summit of the mound at 114.20 m asl. A north to south series of trenches from the summit to the level of the natural soil layer resulted in a max. eight-meter-high section, where marl alternates with clay-rich sediments (Figure 5). The excavated deposits contain a small but informative amount of ceramic material that dates from the Late Bronze Age to the end of the Cypro-Classical period (end of 4th c. BC) and/or the early 3rd c. BC. Hence, a preliminary terminus post quem for the construction of the mound, which would have required the transportation of at least 9.500 m^3 of earth materials, is currently placed no later than the 3rd c. BC.

In 2014, in the process of investigating a built structure of sloping stonework that runs along the east side of the mound, and which was thought to have served as a retaining wall for the containment of the transported earth, we exposed the inner face of an impressive rampart. Constructed with a combination of worked and unworked limestone and well-preserved mudbrick tiles, the rampart also possesses two facing staircases that would have led to towers (Lorenzon & Iacovou, 2019, p. 351, Figure 5). The pottery from the foundation trenches below the two staircases provides a construction date around the transition from the 6th to the 5th c. BC. Founded at 107.20 m. asl and still standing up to 6 m. on its NE corner (at 113 m. asl), this construction is the oldest monument that has been discovered on Laona to date. However, it is not the only one covered by, and preserved within the tumulus. At a depth of 4.50 m from the summit of the tumulus, and 25 m east of the rampart' inner face, a small built monument (4.30 × 3.50 m) was discovered. Its construction was initiated with the excavation of a 5 × 6 m foundation trench that reached down to bedrock (circa 106.00 m asl). Although seen from the outside its walls appear to have been built with dressed blocks, their inner face is unworked, and they are held together with red clay. In fact, this structure has no interior space or content; the stonework created a shell, which was filled with worked marl from the top (max. preserved height at SE corner 109.50 m asl) to bottom (lowest point 106.10 m asl). The shell did not have a roof or a cap; the layers of the tumulus were deposited directly on top of the marly fill contained by the stone walls. Evidence suggests that the marl was crushed and worked into a smooth dark gray mixture in a long trench (4.00 × 1.10 m), which had been dug down to bedrock behind the east wall (consult Figure 4). The trench was found filled with the same mixture of still moist marl that filled the monument's interior.

As a result of exposing the four sides of this anomalous structure from the tumulus layers, highly significant elements facilitated the interpretation of the construction process of the mound (Figure 6). Soon after its construction, the built structure was buried under a small mound, during an illicit operation, which led to the complete dismantlement of the west wall down to the foundation trench. This attempt to enter the built structure is interpreted as a failed looting operation, which allows us to suggest that the purpose of this enigmatic monument may have been to divert prospective looters away from the grave. If the purpose of the built structure was to function as a 'pseudo-grave', then it is more than likely that Laona is a burial tumulus.

As a result of these investigations, it became apparent that the first monument built on the natural hillock of Laona was a fortress. It appears to have been constructed at the same time as the palace and workshop complexes on the citadel of Hadjiabdoullah (Iacovou, 2019, p. 223–225: figs 18–21). Although its excavation is not yet complete, it is evident that the fortress was part of a well-planned and extremely

FIGURE 6 Built monument ('pseudo-grave') seen from the south; vivid sediment colors are visible on a section of tumulus to the north (photo M. Iacovou)

ambitious building program implemented by an early 5th-century BC local dynasty. The second monument revealed (so far) on Laona is the 'pseudo-grave', which was never meant to be exposed to viewers for any length of time. Its construction is assigned to the initial stage of the tumulus building program. It was apparently sealed under the first mound of earth.

The third monument is none other than the tumulus, standing on Laona since the 3rd c. BC, and whose geoarchaeological analysis is the subject of the present article. From the point of view of Cyprus's archaeology, the tumulus of Laona is an extremely rare monument. Although scholars refer to Salamis Tomb 3 (Karageorghis, 1967, p. 25) and Salamis Tomb 77 (Karageorghis, 1973-1974, p. 128–202) as tumuli (cf. Carstens, 2016; Vitti, 2019), it is important to acknowledge that they too are as foreign tothe mortuary landscape of Salamis as Laona is to the landscape of ancient Paphos (cf. Iacovou, 2017, p. 327–328). Besides being very different from each other in terms of their construction, Salamis Tomb 3 and Salamis Tomb 77 belong to two different sociopolitical horizons. Salamis Tomb 3 covers a 'royal' built tomb of the Cypro-Archaic period constructed when Cyprus's city–states were consolidating their territorial authority (cf. Satraki, 2013). Salamis Tomb 77 covers a cenotaph, which has been dated to the period of the conflict between Alexander's Macedonian successors towards the end of the 4th c. BC. The conflict between Antigonus I Monophthalmus and Ptolemy I Soter led to the violent abolition of Cyprus's autonomous city-states and to the establishment of an island-wide colonial administration under the Ptolemaic kingdom of Egypt (cf. Mehl, 2000; Papantoniou, 2012). The cenotaph construction has been recently attributed to Demetrios Poliorcetes, son of Antigonus (Burazelis, 2013; for earlier attributions, Vitti, 2019 with relevant bibliography). If the tumulus on Laona was a monumental place-making enterprise ordered by the 3rd c. BC Ptolemaic rulers of Cyprus, then the only possible connection between the tumulus of Salamis and the tumulus of Laona could be a mound-building tradition of a common Macedonian origin.

3 | METHODOLOGY

Following the excavation strategy of Karkanas et al. (2012) on Mycenean chamber tombs, the excavation of the Laona tumulus was adjusted for the geoarchaeological project's purposes (2017–-2018). Thus, it was decided to formulate an excavation plan, which included the formation of baulks along and across the site, based on a stratigraphic approach that fits the depositional conditions of the creation of the tumulus. The baulks' stratigraphy was recorded by identifying the laterally linear sedimentary features (Figures 5 and 7). In this way, we reconstructed the beds' 3D geometry, which would be impossible to recognize using conventional methods of excavation. Selected sedimentary facies were sampled for micromorphological analysis. Soil micromorphology was used to confirm, refute, and further investigate issues raised during fieldwork related to the identification of building materials and methods of mound construction. Furthermore, taphonomic processes and post-construction pedogenic alterations were reconstructed. Major episodes of mound-building and temporal gaps during construction were also detected, which allowed us to evaluate energy and labor investment.

Geoarchaeology has undoubtedly proven to be a powerful tool to unravel such complex stratigraphic and depositional questions (Karkanas & Goldberg, 2007), yet few geoarchaeological studies have been conducted in tumuli and related earthen structures to this date

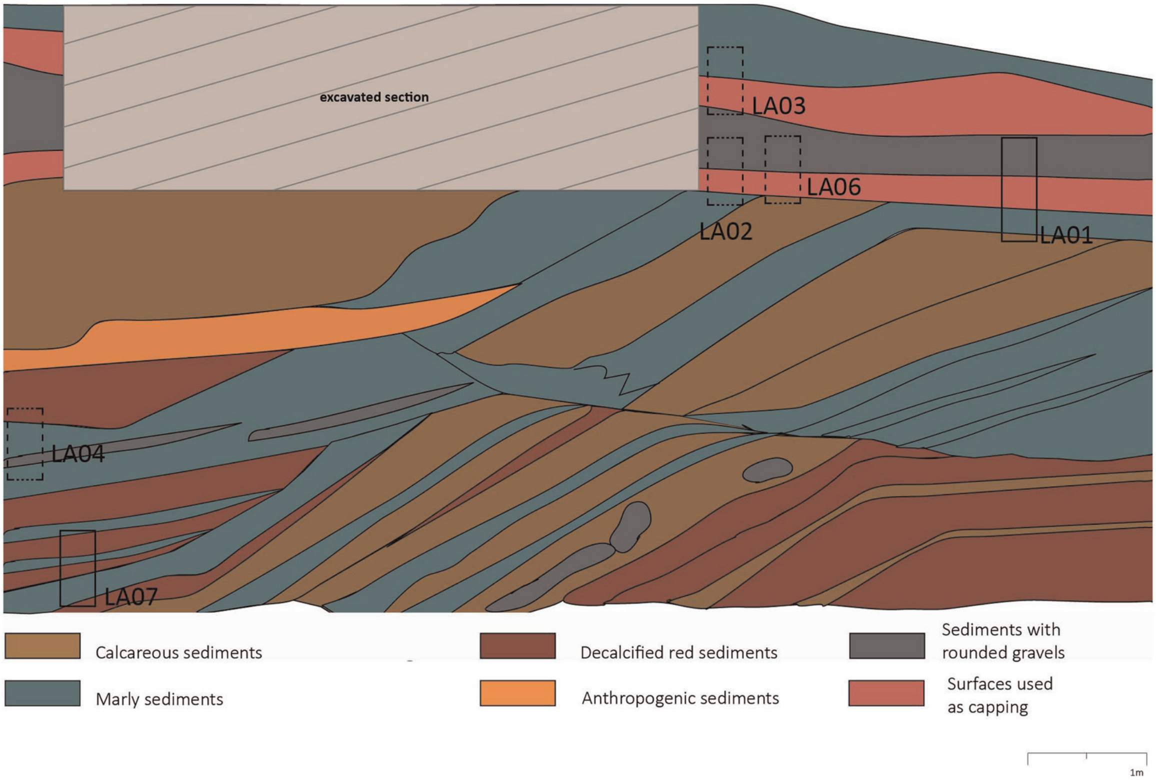

FIGURE 7 Stratigraphic profile of the west section of the tumulus (north to south) showing the facies described in the text. Micromorphological samples are indicated in black rectangles. LA02-04 and LA06 (dashed rectangles) are projected on the profile; they come from adjacent sections so that the stratigraphy can be physically connected with the one depicted in the drawing

(Castiñeira et al., 2013; Cremeens, 2005; Kidder & Sherwood, 2017; Macphail et al., 1998; Maghsoudi et al., 2014; Rizzo & Panizza, 2017; Sherwood & Kidder, 2011; Sherwood et al., 2013; Villagran & Gianotti, 2013).

Micromorphological samples were taken from exposed profiles and surfaces during two consecutive excavation seasons (2017–2018). The sampling strategy was adjusted to cover selected sedimentary facies identified macroscopically in representative parts of the mound (i.e., the crest, the middle part, and the base). In total, eight undisturbed blocks of sediment (monoliths) (Figures 4 and 7) from the archaeological sequence were collected. The sampled blocks' dimensions varied from large monoliths of 35 × 15 × 15 cm to more typical 20 × 10 × 10 cm blocks. The samples were oven-dried at 50°C and then impregnated with polyester resin diluted with acetone. Fifty-two large format thin sections (7 × 5 cm) were prepared and studied. Descriptive terminology of the thin sections follows that of Stoops (2003) and Courty et al. (1989).

4 | RESULTS

4.1 | The construction materials

The construction materials identified in the field are deposited in inclined, parallel, and chaotic beds and are described as follows (Table 1):

4.1.1 | Fills of marly deposits

Marl is the predominant source material used for the construction of the tumulus. It originates from the Miocene marl formation, which dominated the preconstruction landscape of Laona (Figure 1). In the field, marls form tabular loose beds with mostly sharp planar boundaries, averagely 20 cm in thickness. They are unsorted, greenish-gray, angular to sub-rounded gravel- to cobble-sized fragments, the latter being concentrated mostly at the lower parts of inclined surfaces, resulting from the free fall construction technique (see below). They form inclined surfaces at the lower part of the tumulus (Figures 5 and 7), which turn to horizontal at the upper part. The beds are distinct and homogeneous, occasionally though they are mixed with other types of fills (Figure 8). Microscopically marls appear as dark grayish brown, angular to subangular calcareous aggregates, medium to highly separated and accommodated, with scattered oxidation staining (Figure 9(a)).

4.1.2 | Fills of rounded gravels

Rounded gravels originate from the conglomerates of the Pleistocene alluvial fan, which forms the tumulus substrate. The gravels appear chaotic to crudely layered in the field, floating in a finer matrix, moderately to badly sorted, concentrated at the upper part of the mound, less abundantly deposited than marls (Figure 7). They are

TABLE 1 Summary of facies characteristics described in the text

Fill material	Field description	Microscopic observations	Geometry and construction method	Pedofeatures
Marls	Unsorted, greenish-gray, angular to sub-rounded gravel to cobble-sized clasts at the lower parts of the inclined surfaces. Tabular loose beds with mostly sharp planar boundaries, averagely 20 cm in thickness. The beds are distinct and homogeneous, occasionally though they are mixed with other types of fills	Marls appear as dark grayish brown angular to subangular aggregates), medium to highly separated and accommodated, with scattered oxidation staining.	They form inclined surfaces at the lower part of the tumulus, which turns to horizontal at the upper part. Deposited using free-fall construction method	Rarely, gypsum and queras associated with underlying anthropogenic sediment.
Rounded gravels	Chaotic to crudely layered, floating in a finer matrix, moderately to badly sorted. They are concentrated at the upper part of the mound and are generally less abundantly deposited than marls	Gravels are identified as occasionally altered igneous rocks, amphibolites, cherts, and limestones, within a matrix of decalcified red soils, in a structure where larger clasts are embedded in a dense finer groundmass (open porphyric coarse-fine related distribution)	Chaotic structure and freefall construction method	No pedofeatures are associated with gravels
Decalcified red soils	Fe-rich layers of brownish-red sandy loams, 1–10 cm thickness alternating with marls	Brownish red sandy silt loams, in aggregated microstructure, which often exhibit strongly rubified rims. The aggregates are often associated (as coatings) with igneous rocks and minerals. Micro-laminae of decalcified soils alternating with lime-rich laminae, (plaster) are identified at the lower part of the tumulus, capping calcareous soils	Decalcified soils are shaped in inclined surfaces alternating with the marls, at the lower parts of the mound, though they are absent at the upper part of the construction. They are processed with the use of water and of a compaction tool to shape fine laminae	No pedofeatures are associated with decalcified soils
Calcareous soils	Calcareous soils include reddish-brown sediments, occasionally associated with marly fragments.	Aggregates of yellowish-brown sandy silt loams with sand grains of quartz and calcite associated with fragments of marl. Calcified sediments are occasionally mixed with anthropogenic material, lime plaster aggregates, aggregates of construction material, a few bones, and charcoal	Along with anthropogenic materials, calcareous soils are processed and wetted to form distinct sharp surfaces to the overlying fills	Gypsum and queras
Fills of anthropogenic sediments	Distinct and massive beds of pinkish red, fine-grained sediments, with sharp planar boundaries, averagely 10 cm in thickness	A mixture of distinct calcitic aggregates with voids and occasionally spongy or laminated microstructure. Inclusions of pottery sherds, bones, and fragments construction materials. Well sorted and fine-grained with lime plaster texture	The beds are sporadically dispersed in the stratigraphy (4 beds) and are horizontal or slightly inclined	Gypsum and queras

FIGURE 8 Impregnated slab, where the facies described in the text are indicated: 1. calcareous soils; 2. wet-plastered deposits; 3. anthropogenic sediments; 4. homogenous marls; 5. mixed sediments including rounded gravel; and 6. red noncalcareous soils

microscopically identified as occasionally altered igneous rocks, amphibolites, cherts, and limestones (Figure 9(b)).

4.1.3 | Fills of decalcified red soils

Decalcified red soils are formed by the weathering of the igneous gravels of the Pleistocene alluvial fan (Osmond & Stephen, 1957). The soils are brownish red, Fe-rich thin layers of 1–10 cm thickness, alternating with marls, and are deposited in inclined surfaces at the lower parts of the mound, being absent at the upper part of the construction (Figure 7). Microscopically they are described as brownish-red sandy silt loams, in aggregated microstructure, which often exhibits clay coatings. The aggregates are often associated with igneous rocks and minerals, and this observation verifies their volcanic origin. Microlaminae of decalcified soils alternating with calcitic-rich laminae and processed with water and compaction tools are identified at the lower part of the tumulus capping calcified soils (Figure 10(a)). Details of this process are described below.

4.1.4 | Fills of calcareous soils

Calcareous soils originate from the marly substrate's natural soil formations and therefore constitute the paleosurface of the tumulus construction. Macroscopically calcareous soils include reddish-brown sediments, occasionally incorporating marly fragments. In the thin sections, they are recorded as aggregates of light yellowish-brown sandy silt loams with quartz and calcite sand grains, associated with fragments of marl. Most of the tumulus sediments at the central part of the tumulus include calcareous sediments (Figure 7). They are often mixed with anthropogenic material, calcareous nodules, lime-plaster fragments, clay construction fragments, few bones, and charcoal (Figures 10 and 11). Lime plaster is identified microscopically by the presence of a dense calcitic cementing fabric with occasionally shrinkage cracks and a few vesicles and irregular voids with smooth walls. However, the most conspicuous feature is, however, the presence of lime lumps in the form of poorly crystalline calcareous aggregated areas with dark gray appearance and low birefringence, indicating only partial reaction and carbonation (Karkanas, 2007; Macphail & Goldberg, 2019, p. 802-805). Calcareous soils and anthropogenic materials are occasionally processed and wetted to form distinct sharp surfaces to the overlying fills (Figure 10(a); see below).

4.1.5 | Fills of anthropogenic sediments

Anthropogenic sediments are identified in the field as distinct and massive beds of pinkish red, fine-grained sediments, with sharp planar boundaries, averagely 10 cm in thickness. Distinct beds of anthropogenic sediment are observed in the stratigraphy and are horizontal or slightly inclined, overall capping each time the underlying stratigraphy (Figure 7). In the thin-section, they are characterized by a mixture of distinct calcitic aggregates with voids and occasionally spongy or laminated microstructure (Figure 10). Inclusions of pottery sherds, bones, and fragments of construction materials (i.e., wall plasters have been recognized under the microscope as they have been macroscopically identified) indicate the anthropogenic origin of the sediments (Figure 11). Along with calcareous soils, anthropogenic sediments are often processed with water and compaction tools to form distinct sharp surfaces (see below).

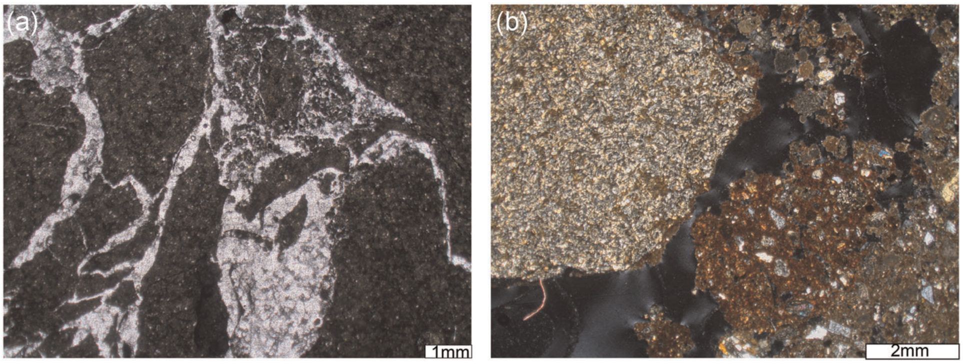

FIGURE 9 (a) Fragments of marls under the microscope (PPL). (b) Rounded igneous gravel associated with red non-calcareous sediments (XPL)

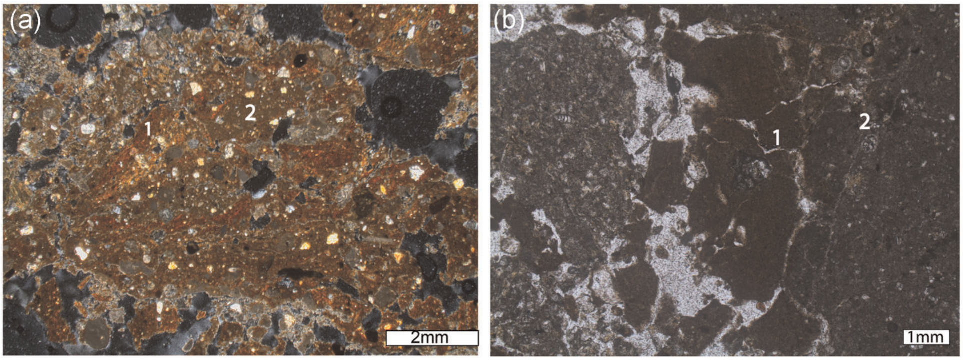

FIGURE 10 (a) Laminations of non-calcareous sediments (1) alternation with lime plaster laminae (2) (XPL) (b) Calcareous sediments (1) associated with marly fragments (2) (PPL)

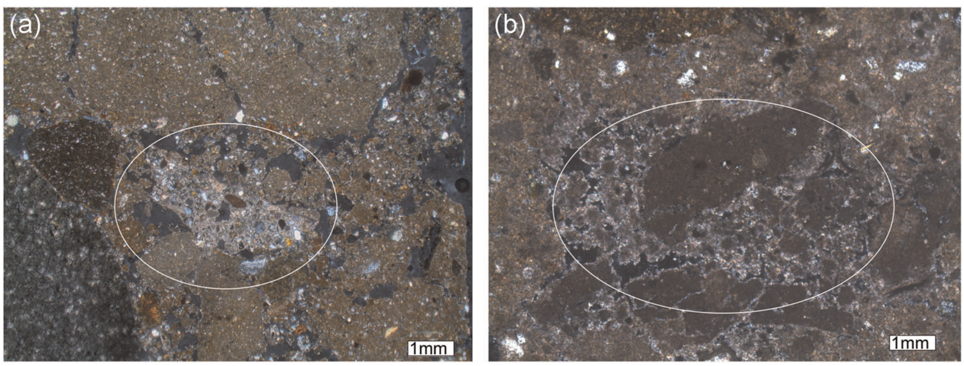

FIGURE 11 (a) A fragment of construction material (wall plaster in circle) in a mixed sedimentary matrix (XPL). (b) Lime plaster aggregate (circle) in a calcareous matrix (XPL)

4.2 | Pedofeatures: Gypsum, queras and clay illuviations

Gypsum pedofeatures are identified under the microscope as nodules and infillings in channels and voids of the earthen fills (Figure 12(a)). They are mainly associated with layers of construction materials. In one case, gypsum is found at the contact of construction materials with marls, in a narrow zone of ca 5 cm, fading upwards and downwards. Gypsum can be inherited from the parent material or formed by early translocation processes of soluble constituents of the parent material by groundwater or soil solutions (Stoops et al., 2018, p. 119). In Laona's case, their clear secondary formation is likely related to the infiltration of water through the fine-grained reused construction materials. This process suggests that gypsum formation has taken place after the deposition of these materials and that the formation horizon was near the surface. The small amount of gypsum found inside the first couple of centimeters of marl above the construction material layer is probably due to secondary capillary action and evaporation leading to the rearrangement of the gypsum crystals after the deposition of the marl.

Queras are pedofeatures formed by the impregnation of root tissues, which are frequently observed in semi-arid soils (Yousefifard et al., 2015). They are here observed as channel infillings of coarse cytomorphic calcite (Figure 12 (b)). These pedofeatures are probably related to the presence of fills of decalcified soils and, as in the case of gypsum nodules and infillings, queras are formed near the surface. Clay coatings and fragments of clay coatings have been recorded locally as products of illuviation, occasionally fragmented and deformed (Figure 12(c)). This process associated with the translocation of rainwater is again indicative of secondary pedofeatures formed close to the surface. Occasionally, more than two of the above pedofeatures appear in the same type of sediment suggesting similar formation conditions.

4.3 | The configuration of the tumulus (stratigraphy)

The excavation strategy, which required the formation of baulks along and across the site, allowed us to observe the internal configuration of the tumulus. In the lower part, inclined beds predominate (Figure 7). They consist mostly of alternating gray marls and noncalcareous red soil beds. These beds show lateral and normal vertical grading, and they are organized in larger piles. A group of parallel inclined beds end up at oppositely, gently inclined surfaces, which probably represent temporary ramps. The result is an impressive colorful bedded arrangement. In between the large piles, the sediments are structureless, without regular bedding.

The central part of the tumulus includes mostly thick structureless beds of a mixture of marls and brownish calcareous soils. Pure thick marl beds are also observed, as well as horizontal alternating beds of marl and calcareous soils. Inclined alternating beds of mostly a mixture of marls and soil material are observed mostly at the periphery of the tumulus making its outer layer. The upper part of the tumulus appears structureless and chaotic, but it is not clear if this represents the final cover or a remnant of the original structure with its upper part being eroded away. Eroded, truncation surfaces capped with anthropogenic sediments are generally observed in the upper part of the tumulus with the most prominent one found between the upper-most fill and the underlying deposits (Figure 7).

Regarding the formation of the tumulus, two main construction techniques have been recorded:

4.3.1 | Freefall

Freefall is the predominant building technique. Each inclined layer shows considerable consistency in grading features and geometry, which suggests formation as a single throwing event. The thickness and length of the layers are indicative of the size of the container utilized for their formation. A big container (like a big barrel or carriage) was most likely used to deposit these graded thick layers,

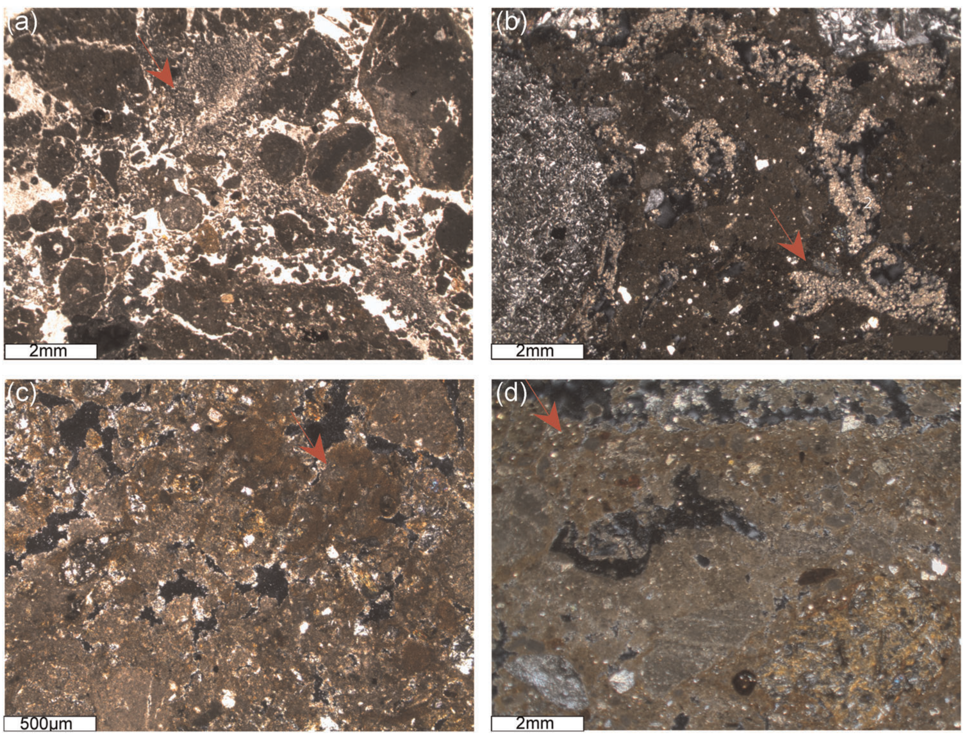

FIGURE 12 (a) Photomicrograph of gypsum infillings (arrow) (PPL). (b) Queras as infillings (arrow) (XPL). (c) Clay illuvial coatings (arrows) (PPL). (d) Crust layer of calcareous soils (arrow) in a mixed matrix with rounded gravels (XPL)

which could not have been formed with the use of smaller equipment. Only at the uppermost part of the tumulus, the sediments' chaotic structure indicates that these were deposited in situ with the capsizing of smaller containers. As piles of soil were shaped, the sediments would spread on their inclined surfaces, mimicking a rockfall or a debris fall, with characteristic normal and lateral grading (Karkanas et al., 2012; Nemec & Kazanci, 1999). Large particles rolled over smaller ones, and small particles would be trapped in the spaces between large ones with the particles' movement downslope. In this case, the coarse particles, having higher kinetic energy, would travel further and thus produce a coarse blanket.

Piles were most likely constructed simultaneously, as there is a consistency in the degree of slope angles and the alternation of the sediments used. The piles eventually coalesced and formed a surface, where materials would be trapped and not moved further by gravity processes, forming depressions filled with deposits in parallel orientation.

Microscopically these processes are identified by the large voids and the sorting of the sediments along with the aggregated microstructure, including highly accommodated and separated aggregates, as a result of in situ breaking (Figure 9).

4.3.2 | Wetting and compaction

Wetting of sediments constitutes a small-scale technique, which can only be identified microscopically. Reused and wetted anthropogenic materials and calcareous soils (enriched with anthropogenic materials) were used as plaster, forming distinct, compacted surfaces, which have been altered through processes related to their long-term exposure including the secondary formation of gypsum and queras.

Wet plastered deposits are found as thin layers of anthropogenic deposits. One of these structures includes two layers (Figure 8). The first is microscopically described as alternating layers of clayey to sandy silt calcareous sediments, finely laminated, with distinct horizontal and vertical channels, possibly indicative of trampling or desiccation. Occasionally the sediments intrude into and deform the underlying layer showing the plasticity of the wet sediments and the pressure that has been applied (Figure 8). Suggestive of the wetting is the vughy to the vesicular microstructure of the fine marl aggregates, which are adjacent to the laminations.

This is overlaid by a second, distinct and extensive but thin, layer of anthropogenic sediments, expanding over the wet plastered deposits in sharp upper and lower boundaries and sealed with a fine crust of fine-grained deposits in laminated microstructure, suggesting that it was wetted after its deposition to form a leveled surface, probably by using a compaction tool.

The same process has been followed at the part of the tumulus which covered the 'pseudo-grave' monument (Figure 7), where a crust-like layer separates the calcitic-anthropogenic deposits from the marls (Figure 12(d)). Another technique was used in the same sequence, including alternating laminae of red decalcified soils, lime, and striated clays, indicating the wetting of sediments, which sealed a layer of calcified sediments with anthropogenic inclusions (Figure 10(a)).

Combined free fall and wetting-compaction techniques are identified in cases where the sediments are originally loosely deposited and in a later stage, they are wetted superficially to form a sharp boundary to the overlying surface. This is verified by the granular microstructure of the underlying sediments capped by a laminated seal.

5 | DISCUSSION

5.1 | The history of the construction of the tumulus

Combining the data above, and considering the geometry and macrostratigraphy of the earthen formation we suggest that the tumulus was formed in the following stages:

I. Initially, the built 'pseudo-grave' (Figure 6) was covered by a small mound. This was mainly constructed using decalcified red soils, calcareous soils mixed with anthropogenic materials and marls. At least two successive surfaces have been identified at this stage, which have been sealed with wetted sediments, using a compaction tool (Figures 10(a) and 12(d)). Both surfaces comprise reused anthropogenic sediments or calcareous soils including anthropogenic debris and they represent the first sealing event of the tumulus. It is suggested that the uppermost surface was exposed for some time, as indicated by the presence of gypsum pedofeatures, before being covered by marl. Nevertheless, it is not apparent whether the second surface represents a repair phase and made almost immediately after the first one or much later. Most likely, the exposure was quite brief, as we do not observe extensive alteration features, as in similar upper surfaces (see below).
II. At a second stage, the central tumulus was constructed. It covered the interior of the rampart (Figure 4) (Lorenzon & Iacovou, 2019). At least two soil piles with inclined beds were formed, which were gradually unified with horizontally deposited materials, including marls and coarser sediments. Leveled surfaces on top of each pile probably served as ramps, on which the carriages were transported to throw the sediments on inclined surfaces. Gradually, with the accumulation of sediments, the ramps would expand and raise, forming extended inclined surfaces.
III. At a third stage, this system of ramps was abandoned, and a second system was introduced on top with surfaces formed in parallel directions. The individual mounds' peak was visibly leveled, and the sediments were deposited horizontally; they were probably compacted. Some of the materials were dampened and trampled, but it seems that they were generally deposited in dry conditions. The second and third stages belong to

the same second construction phase as there is no obvious break between these stages. A second capping layer of anthropogenic material sealed this construction phase.

IV. The final stage of the tumulus construction included at least two repair/maintenance phases. Both of them are associated with small and large truncation and erosional surfaces that have probably resulted from the erosion and collapse of the tumulus upper and peripheral parts. The first repair/maintenance phase is demonstrated by a third capping layer of anthropogenic material. It is parallel to the previous cap that sealed the second phase of the tumulus construction and located several tens of cm above it. The second and final repair followed a major erosional surface which truncated the underlying layer. This final phase of the tumulus' maintenance appears to have been eroded and reworked in places. Therefore, it is not clear if an even more recent anthropogenic cap had existed, which could have been similar to those below.

As already described above, layers of reused anthropogenic materials capped the tumulus. They have been at least partially dampened superficially, to create a very sharp and distinct surface probably with the use of a compaction tool. Moreover, the formation of gypsum infillings and queras in the capping layers demonstrates that this part of the mound has been exposed and close to the surface. Therefore, the reused anthropogenic materials served as sealing, which, among others, prevented the rainwater from infiltrating deeper in the tumulus. Considering this process, we can support the hypothesis that the tumulus underwent at least two phases of building and another two of maintenance indicated by the presence of exposed surfaces, followed by prolonged periods of exposure. These different stages (I–IV) of construction of the tumulus can be seen as a scaled series of archaeological temporalities stretching from the construction of the 'pseudo-grave' to the subsequent stages of building and modifications of the mound. These stages are not continuous; they reflect several temporal cycles of different nature and magnitude superimposed on one another (Olivier, 1999, p.129-130). As the visibility of the original structure increased in parallel with its height, the monument's temporal stability was enhanced (Joyce, 2004) until the tumulus became a physical mark of communal and individual memory.

5.2 | Selection of materials and techniques

The main geotechnical achievement related to the construction of the tumulus is its stability. It is suggested that four main strategies have been considered to accomplish the preservation of the monument.

(1) The alternation of fine-grained marls and coarser raw materials in a consistent pattern must have served a geotechnical, stability purpose. Marls were extracted easily from the natural substrate as big fragments, which leave gaps when redeposited. On the other hand, red soils, having fine granular structure, can fill the gaps between the marl aggregates enhancing the cohesion of the sediments.

(2) Marls have remarkably high moisture content, low dry density, bearing capacity, and strength in shear cases (Arifuzzaman et al., 2017). These characteristics render marls geotechnically hazardous, especially in the case of inclined surfaces. However, the mixture of marls with calcareous sediments could enhance their geotechnical properties. The use of calcareous soils and anthropogenic materials rich in lime even in small proportions could reduce the plasticity and the changes in the volume of marls, increasing their stiffness (Arifuzzaman et al., 2017).

This alternating use of fine and coarse, calcareous, and noncalcareous materials has been recorded in archaeological sites (Evstatiev et al., 2005; Papadopoulos et al., 2008; Syrides et al., 2017) as a means of enhancing the strength and water resistance of the sediments (Evstatiev & Rashev, 1988; Politis et al., 2011). The micromorphological study of the workshop complex on the citadel of Hadjiabdoullah (unpublished, ongoing research) shows that marls, noncalcareous red soils, and lime plasters have been used extensively for the construction of floors, foundation courses, and walls. Clearly, the local masons must have had centuries of experience with these materials in the context of the construction of different built structures. Therefore, the tumulus builders were acting within traditional technical practices employed in the production of secular and ritual edifices (Joyce, 2004).

Moreover, builders contrasted colors and textures, often combining soils of different origin into mixed sediments that were then emplaced in exact stratigraphic locations (Inomata et al., 2020; Kidder & Sherwood, 2017). These uses indicate that many sediments affected more than a purely functional purpose. Even though color symbolism and esthetic appreciation are socially determined and highly specific amongst individual communities, anthropological, and geoarchaeological studies associate the use of colors in construction materials with religious and cosmological notions, the division of the year, time, and space (Boivin, 2000, 2004, Darvill, 2002). Pursell (2013) discusses the use of red and white soils to represent split ideological and social realities. It is suggested that mounds were constructed using deliberately color symbolism and perspective to create ritual space and influence daily practice. In Laona, reused construction materials with an overall pinkish-red color were used to produce a shell for the underlying tumulus. This happened consistently at least three times, each time sealing a main reconstruction phase of the tumulus. In addition to their geotechnical advantages, these distinctive caps may have been used as an indicator of the existence of an artificial, constructed hill and probably served as a statement of the importance of this feature for the living and their descendants.

(3) Finally slope angles and (4) compaction must have played a crucial role in the maintenance of the monument. Slope stability is ultimately determined by two factors: the angle of the slope

and the strength of the materials. The fact that there is a strong consistency in the slope geometry of the different piles, lower than the angle of repose (<30°), indicates that angle degrees were given special attention as part of the construction plan. This technique would ensure that the layers would not collapse under their own weight and that they are inclined to the degree that the clasts would roll down the slope. In certain cases, calcareous sediments have been used as a surfacing medium to enhance the slope layers' stability (Wright, 2009). Compaction has been achieved with the use of wetting and compaction equipment. The role of compaction for the maintenance and integrity of constructions has been recorded in ancient earthen architecture (Evstatiev et al., 2005, Kérisel, 1985, p.23: figure 31), with various methods of compaction and stabilization being used along with suitable slope degrees. Compaction was achieved with simple hand-operated tampers, but more sophisticated machines with dropping weights may have been also used.

6 | CONCLUSIONS: AN UN-CYPRIOT MONUMENT IN THE LANDSCAPE OF THE CYPRIOT GODDESS

The tumulus of Laona is an unprecedented monument in the cultural history of Cyprus. The geoarchaeological research at Laona has highlighted the variability in the construction materials and the techniques used for building the tumulus. It is evidenced, that the application of specific techniques and the alternating use of selected raw materials enhanced the sediments' geotechnical properties to achieve maximum maintenance of the massive construction. When natural sediments were not suitable for the solidity of the mound, provision was taken, and the materials were complemented with elements that lend structural cohesion. In this sense, the labor investment in building engineering is closely related to the permanence of the structure, emphasizing the planned character of the tumulus (Castiñeira et al., 2013).

All the above characteristics, materials, and techniques indicate that the tumulus of Laona was created by trained builders with an established experience and knowledge of the properties of the sediments. Each stage of the building process was challenging and demanded labor allocation and planning. The implementation of such a demanding building project would have required management and leadership to organize the collective work of moving sediments and erecting earth structures, as has also been suggested for the manufacture of the mold-made mudbricks used in the construction of the earlier rampart sealed under the mound (Lorenzon & Iacovou, 2019). Moreover, the construction process required a series of decisions that reflect cultural choices and shared knowledge in communicating specific information (Kidder & Sherwood, 2017; Sherwood & Kidder, 2011). The building of monuments was not only architecturally important as a means to serve a subsequent purpose; the act of construction itself was a cultural process intended to serve its own social purposes.

As the investigation and analysis of the monuments of Laona continues, the results of the present study confirm that the tumulus was not a product of earth accumulation over an earlier monument (i.e., the fortress), but an accomplished architectural artifact designed to remain intact. Although foreign to the cultural system of Cyprus, the tumulus of Laona survived from the 3rd c. BC to the 21st c. AD. It continues to loom large in the landscape of Kouklia-Palaepaphos because the demands of its construction had been successfully met by local masons, whose intimate knowledge of the properties of locally available earthen construction materials has been fully documented in the present study. Even though, for the time being, the initiation of its construction cannot be dated with precision, the Laona tumulus is chronologically and culturally associated with the period of the Wars of the *Diadochi* and the early Ptolemaic era (cf. Mehl, 2000). The conflict between Antigonus and Ptolemy I Soter in Cyprus ended in favor of the latter and with the dramatic termination of the island's segmented political geography. Under Ptolemaic rule, Cyprus became, for the first time, a unified but colonial state (cf. Iacovou, 2007, p. 464; Papantoniou, 2013a).

From the perspective of Paphos, the events associated with the abolition of the local dynasty, and the death of Nikokles (circa 310 BC), the last *basileus* (king) of Paphos and priest of the *wanassa* (goddess), were cruel and traumatic (Diodorus 20.21.2–3). The citadel of Hadjiabdoullah lost its political status; however, the foremost politico-religious identity symbol of the Paphian city-state, the sanctuary of the Cypriot goddess, with the iconic megalithic temenos, was employed by the new rulers to serve a new role. It was made into the island's first Pancyprian cult center (cf. Papantoniou, 2013b, p. 48). The redefinition of the sanctuary's indigenous identity (from region-specific to island-wide) by an exogenous political authority (cf. Iacovou, 2019) is not unrelated to Laona's drastic transformation: until sometime in the 4th c. BC, it was a fortress of the autochthonous royal dynasty of Paphos; sometime in the 3rd c. BC it was transformed into an un-Cypriot mound, whose intervisibility with the sanctuary remains prominent to this day.

'The exact political, social, and cultural organization of Hellenistic Cyprus, and particularly of the early years (*grosso modo* the third century BC), remains unknown.' (Papantoniou, 2013a, p. 169). Not surprisingly, the identity of the agent behind the construction of the tumulus of Laona in the early years of the Hellenistic period is also unknown. However, the explicit desire of this political agency was to redefine the landscape with a pronounced but un-Cypriot landmark that was meant to convey a now lost message to future generations.

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REFERENCES

Agapiou, A. (2013). Development of remote sensing methodologies for the detection of buried archaeological remains [Greek]. Unpublished Ph.D. Dissertation, Technological University of Cyprus.

Alcock, S. E. (2016). Time traveling tumuli. The many lives of bumps on the ground. A general introduction. In O. Henry & U. Kelp (eds.), Tumulus as Sema. Space, politics, culture and religion in the first millennium BC. Berlin - Boston: De Gruyter, 1–8.

Arifuzzaman, M., Najjar, M., Mahmud, M. N., Islam, A. S., Khan, M., & Ali, M. M. (2017). Enhancing the properties of marl soils for effective construction in Saudi Arabian region. *Engineering Journal*, *21*, 111–126.

Boivin, N. (2000). Life rhythms and floor sequences: excavating time in rural Rajasthan and Neolithic Çatalhöyük. *World Archaeology*, *31*(3), 367–388.

Boivin, N. (2004). Geoarchaeology and the goddess Laksmi: Rajasthani insights into geoarchaeological methods and prehistoric soil use. In N. Boivin and M.-A. Owoc (eds.), *Soils, stones and symbols: cultural perceptions of the mineral world* (pp. 165–186). London: UCL Press.

Burazelis, K. (2013). The problem of the royal cemetery of Salamis: a new proposal [Greek]. In Michaelides, D. (ed.), Epigraphy, numismatics, prosopography and history of Ancient Cyprus. Papers in honour of Ino Nicolaou Uppsala: Studies in Mediterranean Archaeology Pocket Book, 293-306.

Carstens, A. M. (2016). Tumuli as power political statements. On tumuli in Cyprus in an East Mediterranean and Anatolian context. In O. Henry και U. Kelp (eds.), Tumulus as Sema. Space, politics, culture and religion in the first millennium BC. Berlin - Boston: De Gruyter, 43-53.

Castiñeira, C., Blasi, A., Politis, G., Bonomo, M., Del Puerto, L., Huarte, R., Carbonari, J., Mari, F., & García-Rodríguez, F. (2013). The origin and construction of pre-Hispanic mounds in the Upper Delta of the Paraná River (Argentina). *Archaeological and Anthropological Sciences*, *5*, 37–57.

Courty, M. A., Goldberg, P., & Macphail, R. (1989). *Soils and micromorphology in archaeology*, Cambridge. Cambridge University Press.

Cremeens, D. L. (2005). Micromorphology of Cotiga Mound, West Virginia. *Geoarchaeology: An International Journal*, *20*, 581–597.

Darvill, T. (2002). White on blonde: Quartz pebbles and the use of quartz at Neolithic monuments in the Isle of Man and beyond. In Jones, A. and MacGregor, G. (eds.), *Colouring the Past: The Significance of Colour in Archaeological Research* (pp. 73–91). Oxford: Berg.

Evstatiev, D., Gergova, D., & Rizzo, V. (2005). Geoarchaeological characteristics of the Thracian Tumuli in Bulgaria. *Helis*, *4*, 156–168.

Evstatiev, D., & Rashev, R., 1988. Engineering geological conditions of the earliest Bulgarian capitals of Pliska and Preslav. In Engineering geology of ancient works, monument and historical sites, Athens, 19–22 September, A. A. Balkema, Rotterdam, 1679–1685.

Gergova, D., Evstatiev, D., & Rizzo, V. (2005). Geoarchaelogical characteristics of the Thracian tumuli in Bulgaria. In Investigations, results and problems in "Sborianovo, Marin Drinov Academic Publishing House, Sofia, 156–168.

Iacovou, M. (2007). Advocating cyprocentricism: An indigenous model for the emergence of state formation on Cyprus. In S. W. Crawford, A. Ben-Tor, J. P. Dessel, W. G. Dever, A. Mazar, and J. Aviram (eds.), Up to the Gates of Ekron. Essays on the archaeology and history of the Eastern Mediterranean in honor of Seymour Gitin, Jerusalem, 461–475.

Iacovou, M. (2008). The Palaepaphos Urban Landscape Project: theoretical background and preliminary report 2006–2007. *Report of the Department of Antiquities, Cyprus*, 263–289.

Iacovou, M. (2013). Paphos before Palaepaphos. New approaches to the history of the Paphian kingdom. D. Michaelides *Epigraphy, numismatics, prosopography and history of Ancient Cyprus, Papers in Honour of Ino Nicolaou*, Studies in Mediterranean Archaeology Pocket-book, Uppsala, 179, 275–291.

Iacovou, M. (2014). Political economies and landscape transformations. The case of ancient Paphos. In J.M. Webb (ed.), Structure, measurement and meaning: Insights into the prehistory of Cyprus. Studies on prehistoric Cyprus in honour of David Frankel, Studies in Mediterranean Archaeology, Uppsala, 143, 161–174.

Iacovou, & M. (2017). The tumulus of Palaepaphos-Laona. From identification to a method of investigation (in Greek). In V. Vlachou and A. Gadolou. (eds.), ΤΕΡΨΙΣ. Studies in Mediterranean Archaeology in Honour of Nota Kourou. Brussels, 307–319.

Iacovou, M. (2019). Palaepaphos. Unlocking the landscape context of the Sanctuary of the Cypriot Goddess. *Open Archaeology*, *5*(1), 204–234.

Iacovou, M., & Karnava, A. (2019). An administrative ostrakon from Kouklia-Hadjiabdoulla. *Cahier du Centre d'Études Chypriotes*, *49*, 2019.

Inomata, T., Triadan, D., Vázquez López, V. A., Fernández-Diaz, J. C., Omori, T., Méndez Bauer, M. B., García Hernández, M., Beach, C., Cagnato, T., Aoyama, K., & Nasu, H. (2020). Monumental architecture at Aguada Fénix and the rise of Maya civilization. *Nature*, *582*, 530–533.

Joyce, R. A. (2004). Unintended consequences? Monumentality as a novel experience in formative Mesoamerica. *Journal of Archaeological Method and Theory*, *11*, 5–29.

Karageorghis, V. (1967). Excavations in the Necropolis of Salamis I, Nicosia.

Karageorghis, V. (1973–1974). Excavations in the Necropolis of Salamis III, Nicosia.

Karkanas, P. (2007). Identification of lime plaster in prehistory using petrographic methods: A review and reconsideration of the data on the basis of experimental and case studies. *Geoarchaeology*, *22*(7), 775–796.

Karkanas, P., Dabney, M. K., Smith, R. A. K., & Wright, J. C. (2012). The geoarchaeology of Mycenaean chamber tombs. *Journal of Archaeological Science*, *39*, 2722–2732.

Karkanas, P., & Goldberg, P. (2007). Micromorphology of sediments: Deciphering archaeological context. *Israel Journal of Earth Sciences*, *56*, 63–71.

Karkanas, P., & Goldberg, P. (2019). *Reconstructing archaeological sites: Understanding the geoarchaeological matrix*. John Wiley & Sons.

Kérisel, J. (1985). The history of geotechnical engineering up until 1700. International Conference on Soil Mechanics and Foundation Engineering.

Kidder, T. R., & Sherwood, S. C. (2017). Look to the earth: the search for ritual in the context of mound construction. *Archaeological and Anthropological Sciences*, *9*, 1077–1099.

Lorenzon, M., & Iacovou, M. (2019). The Palaepaphos-Laona rampart. A pilot study on earthen architecture and construction technology in Cyprus. *Journal of Archaeological Science: Reports*, *23*, 348–361.

Macphail, R. I., & Goldberg, P. (2019). Archaeological materials. In Stoops, G., Marcelino, V. & Mees, F. (eds), *Interpretation of micromorphological features of soils and regoliths* (2, pp. 779–819). Amsterdam: Elsevier Science.

Macphail, R. I., Cruise, G. M., Mellalieu, S. J., Niblett, R., Bond, S., Dormor, I., & Reeves, K. (1998). Micromorphological interpretation of a "turf-filled" funerary shaft at St. Albans, United Kingdom. *Geoarchaeology: An International Journal*, *13*, 617–644.

Maghsoudi, M., Simpson, I. A., Kourampas, N., & Nashli, H. F. (2014). Archaeological sediments from settlement mounds of the Sagzabad Cluster, central Iran: Human-induced deposition on an arid alluvial plain. *Quaternary International*, *324*, 67–83.

Maier, F.-G. (2004). *Guide to Palaipaphos (Kouklia)*. Nicosia.

Mehl, A. (2000). Hellenistic Cyprus [in Greek]. In T. Papadopoullos (Ed.), *Istoria tes Kyprou* (2, pp. 619–761). Nicosia.

Nemec, W., & Kazanci, N. (1999). Quaternary colluvium in west-central Anatolia: Sedimentary facies and palaeoclimatic significance. *Sedimentology*, *46*, 139–170.

Olivier, L. (1999). The Hochdorf 'princely' grave and the question of the nature of archaeological funerary assemblages. In T. Murray (ed.), *Time and archaeology* (pp. 109–138). London: Routledge.

Osmond, D. A., & Stephen, I. (1957). The micropedology of some red soils from Cyprus. *Journal of Soil Science*, *8*, 19–26.

Papadopoulos, J. K. (2006). Mounds of memory: burial tumuli in the Illyrian landscape. In Bejko, L. & Hodges, R. (Eds.), *New directions in Albanian archaeology: Studies presented to Muzafer Korkuti* (pp. 75–84). Tirana: International Center for Albanian Archaeology.

Papadopoulos, J. K., Bejko, L., & Morris, S. P. (2007). Excavations at the prehistoric burial tumulus of Lofkënd in Albania: a preliminary report for the 2004-2005 seasons. *American Journal of Archaeology*, *111*(1), 105–147.

Papadopoulos, J. K., Bejko, L., & Morris, S. P. (2008). Reconstructing the prehistoric burial tumulus of Lofkënd in Albania. *Antiquity*, *82*, 686–701.

Papantoniou, G. (2012). *Religion and social transformations in Cyprus: From the Cypriot Basileis to the Hellenistic Strategos*. Leiden: Brill.

Papantoniou, G. (2013a). Cypriot autonomous polities at the crossroads of Empire: the imprint of a transformed islandscape in the Classical and Hellenistic periods. *Bulletin of the American Schools of Oriental Research*, *370*, 169–205.

Papantoniou, G. (2013b). Cyprus from Basileis to Strategos: a sacred-landscapes approach. *American Journal of Archaeology*, *117*, 33–57.

Politis, G. G., Bonomo, M., Castiñeira, C., & Blasi, A. (2011). Archaeology of the Upper Delta of the Paraná River (Argentina): mound construction and anthropic landscapes in the Los Tres Cerros locality. *Quaternary International*, *245*, 74–88.

Pursell, C. C. O., 2013). Colored monuments and sensory theater among the Mississippians, In (Ed.), J. Day *Making senses of the past: toward a sensory archaeology*. (40, pp. 69–89). Carbondale: Southern Illinois University Press

Rizzo, V., & Panizza, M. (2017). An unusual tumulus or cenotaph at Cozzo Rotondo, town of Grifone (Bisignano, Cosenza, Italy). New and old geological investigation for an archaeological discovery. *Groma*, *2*, 49–63.

Satraki, A. (2013). The Iconography of Basileis in Archaic and Classical Cyprus: manifestations of royal power in the visual record. *Bulletin of the American Schools of Oriental Research*, *370*, 123–144.

Sherwood, S. C., Blitz, J. H., & Downs, L. E. (2013). An integrated geoarchaeology of a late woodland sand mound. *American Antiquity*, *78*, 344–358.

Sherwood, S. C., & Kidder, T. R. (2011). The DaVincis of dirt: geoarchaeological perspectives on Native American mound building in the Mississippi river basin. *Journal of Anthropological Archaeology*, *30*, 69–87.

Stoops, G. (2003). *Guidelines for analysis and description of soil and regolith thin sections.*Soil Science Society of America.

Stoops, G., Marcelino, V., & Mees, F. (2018). *Interpretation of micromorphological features of soils and regoliths*. Elsevier.

Syrides, G., Pavlides, S., & Chatzipetros, A. (2017). The geological structure of Kastas hill archaeological site, Amphipolis, eastern Macedonia, Greece. *Bulletin of the Geological Society of Greece*, *51*, 38–51.

Villagran, X. S., & Gianotti, C. (2013). Earthen mound formation in the Uruguayan lowlands (South America): micromorphological analyses of the Pago Lindo archaeological complex. *Journal of Archaeological Science*, *40*, 1093–1107.

Vitti, P. (2019). In S. Rogge, C. Ioannou, & T. Mavrojannis (Eds.), An Archaic Vault in Tomb 3 of Salamis: Architecture, function and symbolism. *History and Archaeology from the Earliest Times to Late Antiquity*. (143–176). Münster: Waxmann.

Wright, G. R. H. (2009). *Ancient building technology* (3). Construction Leiden: Brill.

Yousefifard, M., Ayoubi, S., Poch, R. M., Jalalian, A., Khademi, H., & Khormali, F. (2015). Clay transformation and pedogenic calcite formation on a lithosequence of igneous rocks in northwestern Iran. *Catena*, *133*, 186–197.

Zomeni, Z. (2012). *Quaternary marine terraces on Cyprus: constraints on uplift and pedogenesis, and the geoarchaeology of Palaipafos*. Unpublished PhD Dissertation Oregon State University.

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