Special Issue: The Apidima Legacy Collections: New Analyses and Interpretations

New Radiometric Dates for the Apidima Caves C and D (Greece) Upper Paleolithic Legacy Collections

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ABSTRACT

Apidima, located in Mani, Southern Greece, is one of the most important paleoanthropological sites in southeast Europe. The cave complex (Caves A-E) was investigated in the 1970s and 1980s by Prof. T. Pitsios of the Museum of Anthropology, University of Athens Medical School. The Pitsios excavations produced rich Middle and Upper Paleolithic assemblages and two Middle Pleistocene fossil human crania from Cave A, but also a hypothesized Aurignacian burial, lithics, and potential ornaments from Cave C, and Upper Paleolithic cultural remains from Cave D. These finds remained largely unstudied until recently, and the Cave C and D assemblages still lack a chronological framework. Here, we present the first absolute dating results from the Pitsios Upper Paleolithic legacy collections, comprising both U-series and radiocarbon dating approaches, which are consistent with the cultural attribution (determined by the recent re-evaluation of this material by our team) of the lithic assemblages of Cave C and D to the Protoaurignacian and early Epigravettian, respectively. The U-series results on the travertine capping the original sedimentary sequence of Cave C provide a minimum age of ca. 29.7 ka BP for the Cave C original sediments. However, calibrated radiocarbon dates on three pierced shells possibly associated with the human skeleton Apidima 3, range between 24.5 and 31.8 ka cal BP, suggesting that at least some of the proposed personal ornaments, and potentially also the human skeleton, are younger than the Protoaurignacian lithic assemblage and possibly intrusive to the sequence. Dates obtained from five mollusc shells from the Cave D legacy collection, range between 17.1 to 22.7 ka cal BP, consistent with our attribution of the cultural remains from the Pitsios excavation in that cave to the Epigravettian.

INTRODUCTION

The Apidima cave complex has yielded Paleolithic cultural, faunal and human skeletal assemblages from the Middle to Late Pleistocene (Harvati 2022; Harvati et al. 2009, 2021; Tourloukis and Harvati 2018). Field investigations conducted by T. Pitsios in the 1970s and 1980s uncovered two Middle Pleistocene fossil human crania from Cave A (e.g., Pitsios 1995; see also Harvati et al. 2011; 2019), but also Upper Paleolithic assemblages excavated from Caves C and D, including a hypothesized Aurignacian burial from Cave C (Pitsios 1995), as well as hitherto unpublished cultural remains from Cave D. Despite the rarity of early Upper Paleolithic sites in Greece (see, e.g., Harvati et al. 2009; Tourkoukis and Harvati 2018), and of Aurignacian human burials generally in Europe (d'Errico and Vanhaeren 2015; Riel-Salvatore and Gravel-Miguel 2013) these remains are understudied and still lack a chronological framework. Here we present U-series and radiocarbon results from the Cave C and D legacy collections, providing chronological constraints on this important material.

The Apidima cave complex (western Mani), comprises five caves, designated A–E and formed in Middle Triassic-Upper Eocene limestone (Figure 1) on a steep coastal cliff. Prof. T. Pitsios and his team from the Museum of Anthropology (School of Medicine, National and Kapodistrian University of Athens) conducted field investigations there, including excavation of caves A-D, between 1978 and 1986. The Pitsios excavation of Cave C (situated at ca. 19 meters above current sea level; see Figure 1) yielded a partial human skeleton, preserving mainly postcranial remains and only a few fragmentary craniodental elements, reported as an Upper Paleolithic burial (Ligoni and Papagrigorakis 1995; Mompherratou and Pitsios 1995; Naumann et al. 2026 [this issue]); a lithic assemblage, described as potentially Aurignacian on the basis of 65 studied pieces (Darlas 1995); >40 pierced *Triria neritrea* shells, potentially representing personal ornaments associated with the burial (Karali 1995); and a rich faunal assemblage, much of it described as burned (Lax 1995; Tsoukala 1999). The Cave C faunal elements reported by Tsoukala (1999), including the giant deer (*Megaloceros* sp.) and an elephantid specimen only tentatively assigned to *P. antiquus* but formally described as "Elephantidae," are present in Europe during the chronological interval of the Upper Paleolithic.

Since 2024, our team has been conducting a comprehensive re-evaluation of the legacy Apidima collections, in the framework of the ERC Project FIRSTSTEPS and with permit from the Hellenic Ministry of Culture (ΑΔΑ: 6Σ0Σ46NKOT/44Z) under the auspices of the Norwegian Institute at Athens. In this context, Lombardo et al. (2026a [this issue]) examined the totality of the lithic assemblage from Cave C, which includes more than 900 lithic artifacts, and attributed it to the Protoaurignacian on the basis of techno-typological analysis and exclusion of alternative potential attributions. Additionally, Naumann et al. (2026 [this issue]) re-examined the Cave C human remains, and found that the skeleton's (Apidima 3) relatively large height and body proportions align more closely with the generally taller pre-Glacial Maximum European populations. This finding tentatively supports an early Upper Paleolithic attribution for the remains. The faunal assemblage and shell beads are currently under re-assessment. New excavations of the *in situ* sediments below the Pitsios excavation, conducted by our team since 2022 under the auspices of the Norwegian Institute at Athens, have continued to yield rich cultural material from Cave C.

The dating of the Cave C legacy finds, as well as their association with each other, are uncertain. Detailed contextual information for this legacy material is lacking and no excavation notes or diaries could be found. Pitsios (1985)

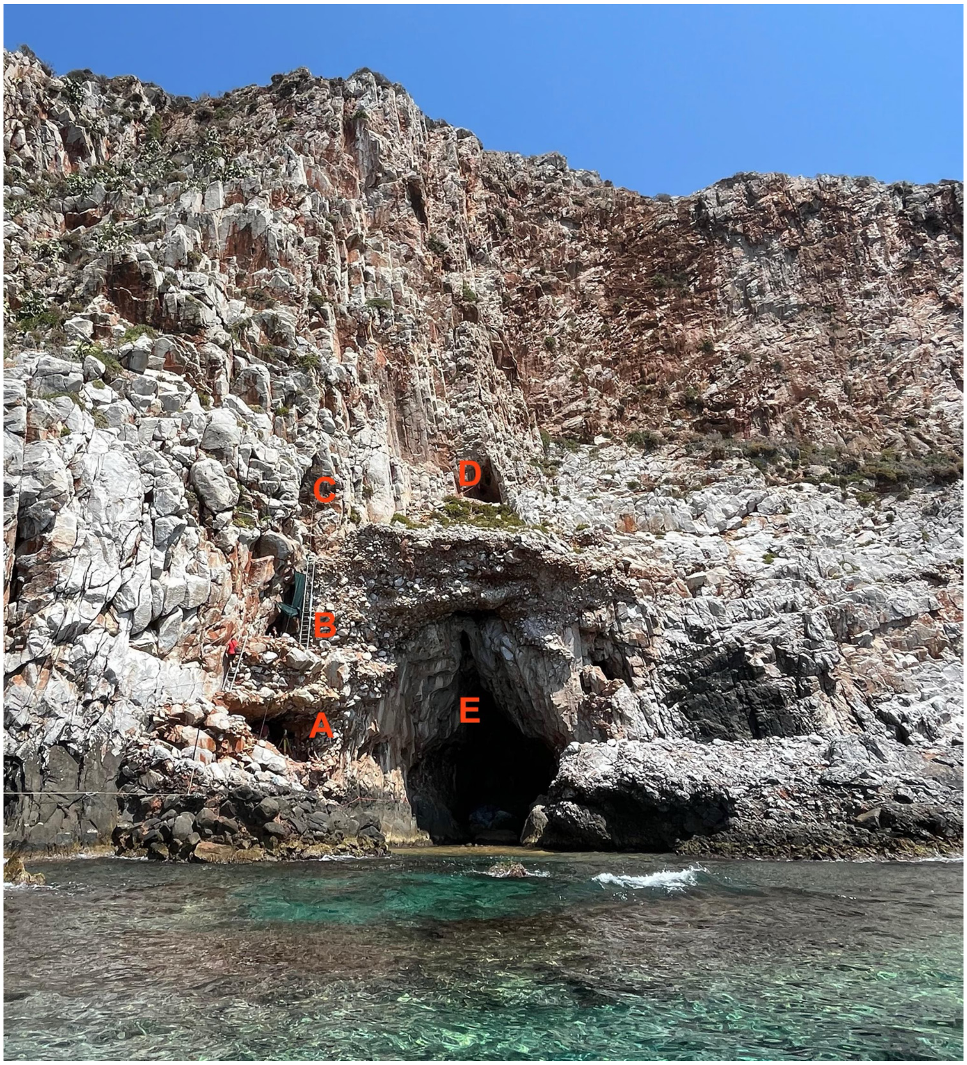

Figure 1. The Apidima cave complex, with Caves A-E labeled in red. Caves C and D are the highest ones in elevation.

mentions three stratigraphic layers in Cave C: C-I, C-II, and C-III, while Pitsios and Liebhaber (1995) provide limited information on the spatial distribution in the form of a section drawing with finds plotted by spit (Pitsios and Liebhaber 1995: Figure 3), but information on the stratigraphic horizons is absent. The Museum of Anthropology archives also include a section drawing of the site with Caves A-C drawn to scale and a photograph of the Cave C excavation, as well as limited information from find tags, when present, such as ID number, elevation below datum, excavation square, and quad. Few attempts at radiometric dating have been undertaken until now. Although Pitsios (1999) reports a date of ca. 30 ka for the Cave C remains, this is, according to Pitsios himself, 'an approximation,' which stems from his hypothesized association of the human remains with potentially Aurignacian lithics (Darlas 1995), and from U-series dates of 25–45 ka and 20–30 ka obtained from travertine samples by Liritzis and Maniatis (1995) (Pitsios 1999: 7). However, the samples dated by Liritzis and Maniatis derive from the openings of Caves B and D, respectively (Liritzis and Maniatis 1995: 87–88; see also Harvati et al. 2009; 2021), and therefore are unrelated to the assemblages from Cave C (Liritzis and Maniatis 1995). More recently, a direct U-series date obtained on human remains from Cave C (poor collagen preservation precluded ^{14}C dating) yielded terminal Pleistocene minimum ages, with the two samples from the Apidima 3 sternum producing minimum U-series ages of 9.9±1.0 ka and 15.4±1.8 ka (Harvati et al. 2021). As these are minimum ages, they do not per se exclude an earlier Upper Paleolithic cultural affiliation (Harvati et al. 2021); however, they also do not clarify the relationship between the skeleton and the Protoaurignacian cultural material (Harvati et al. 2021; see also Karakostis et al. 2026 [this issue]; Lombardo et al. 2026a [this issue]; Naumann et al. 2026 [this issue]).

Even less information exists about the work conducted by Pitsios in Cave D. Here only find tags and the section profile (adapted in Figure 5) are available. This is the highest cave of the Apidima complex, situated ca. 24 meters above sea level (see Figure 1). Pitsios (1985) and Lax

Figure 2. The black thin staining band, indicated by the white arrows, observed along the walls of Apidima Cave C, which marks the level of the former sedimentary fill of the cave.

(1995) mention the Cave D stratigraphic sequence as including a culturally sterile layer, followed by a thick layer of natural salt, with a rich layer just below it, comprising lithics, molluscs, and fossil fauna (see also Lombardo et al. 2026b [this issue]). The latter is described in Lax (1995) as highly fragmented and largely burned, and comprising small and large mammals, birds, and amphibians, including carnivores. Only a preliminary assessment of a sample of the Cave D lithics was published previously (Kourtessi-Philippakis 2007). Our recent comprehensive re-analysis of this material supports an early Epigravettian cultural attribution (Lombardo et al. 2026b [this issue]). New excavations of Cave D by our team since 2025, conducted under the auspices of the Norwegian Institute at Athens have revealed that the find-rich sediments continue below the layers excavated by Pitsios. No radiometric dates have been published for the Cave D assemblages until now. A date of 20–30 ka was obtained from travertine samples from the opening of Cave D by Liritzis and Maniatis (1995). However, it is unclear how that sample relates to the cultural assemblage, if at all.

Here we report a U-series date for a travertine sample capping the Pitsios excavated sequence in Cave C, as well as radiocarbon dates obtained on shells from the legacy collections of both Caves C and D with the goal of placing these important finds in a robust chronological framework for the first time.

MATERIALS AND METHODS

U-series dating: Along the walls of Cave C a black thin staining band is observed, probably made of iron-manganese material, marking the level of the former sedimentary fill of the cave (Figure 2). The band ends at the top of the *in situ* sediment remains still present at the back of the cave and continues towards the front, forming a flowstone crust on top of a thin remnant of cemented sediment (breccia) there. Another small remnant of cemented sediment is observed along this band towards the back of the cave. This crust is considered to cap the sediments excavated by Pitsios, and was sampled for U-series analysis (sample APU5; Figure 3).

U-series dating of the Apidima carbonate sample APU5 was carried out at Nanjing Normal University, China, using a laser ablation system coupled to a multi-collector inductively coupled plasma mass spectrometer (LA-MC-ICP-MS). A small piece of carbonate sample with diameter of ~2cm was cut from the initial specimen using a wire saw (d=0.3mm). It was subsequently polished to obtain a flat surface and then fixed in a sample holder for laser ablation analyses.

The MC-ICP-MS instrument was equipped with one ion counter and nine Faraday cups (Jiao et al. 2024). For U-Th isotopic measurements, pairs of adjacent spots were ablated—one spot was used to measure ^{232}Th, ^{234}U, ^{235}U, and ^{238}U, and the adjacent spot was used to measure ^{230}Th, ^{232}Th, ^{235}U, and ^{238}U.

To correct for detrital Th contamination, the Rosholt Type-II isochron method was applied (Ludwig and Titterington 1994). The isochron construction involved two diagrams (i) plotting the ^{234}U/^{232}Th versus the ^{238}U/^{232}Th activity ratios and (ii) plotting the ^{230}Th/^{232}Th versus the ^{238}U/^{232}Th

Figure 3. The small remnant of cemented sediment associated with the black staining band towards the back of the cave, where sample APU5 was obtained from the flowstone considered to have capped the sediments excavated by Pitsios.

activity ratios. The slopes of these regressions yield the $^{234}U/^{238}U$ and $^{230}Th/^{238}U$ activity ratios required for age calculations. All isochron analyses were carried out with the isoplot add-in for Excel (Ludwig 2001). All isotope data and ages are given with 2-σ errors.

Radiocarbon dating: Three perforated shells of *Tritia neritea* (specimens E288.2, E507.2, E560) from the Cave C legacy collection were selected for direct ^{14}C dating. Of these, the elevation of specimen E288.2 is indicated on its tag, allowing for it to be plotted in Figure 4. Additionally, five mollusc shells of *Phorcus sp.* from the Cave D legacy collection were selected for direct dating. The shell samples were physically cleaned and sub-sampled at the Higham Lab, University of Vienna, and chemically processed at the Centre for Climate, the Environment & Chronology at Queen's University Belfast, UK. The shell samples were first washed using Milli-Q water and hydrochloric acid prior to being hydrolyzed with phosphoric acid to evolve CO_2 before being measured at the AMS (details in Santos et al. 2004). Radiocarbon dates are reported in radiocarbon years BP (before present = AD 1950) using the half-life of 5568 years. Isotopic fractionation has been corrected for using the $\delta^{13}C$ values measured on the AMS and are not reported. For carbonates, the $\delta^{13}C$ values of the evolved gas are not measured by all labs at an EA/ AGE-3 system, but instead the gas is reduced to graphite on iron catalyst using the hydrogen reduction method on a graphitization line. Therefore no $\delta^{13}C$ values are available.

Stratigraphic context: We used all available information, including data and graphs from Pitsios' publications and information recorded on excavation tags and photographs from the Museum exhibits and archives, to reconstruct as far as possible the context of the legacy finds from the two caves and their relationship to our radiometrically dated samples, in order to shed light on the chronology of these important collections. Notably, Figure 3 of Pitsios and Liebhaber (1995) was used as a baseline for reconstructing the Pitsios excavation of Cave C.

Elevations reported in Mompheratou and Pitsios (1995) for human remains and shell beads were used to estimate the position of the specimens that were directly dated in this study, as well as previously (Harvati et al. 2021), using the datum point used by Pitsios, which, together with the trench points of his excavation, were identified with relative certainty on the walls of Cave C and incorporated in the grid of our current excavation at the cave (see Figure 4). The N-S cave profile of Figure 4 was created from point cloud data captured with the Polycam 3D software, run on an Apple iPad Pro.

The reconstruction of the Cave D Pitsios excavation was more difficult, and was based on the published descriptions. Here the Pitsios excavation datum could not be identified with certainty on the cave walls, therefore individual specimens from the legacy collection could not be plotted (Figure 5).

RESULTS

U-series analysis: The carbonate sample APU5 shows the alternate condense (dark) and porous (white) laminae (Figure 6A). Two U-series transects were performed on

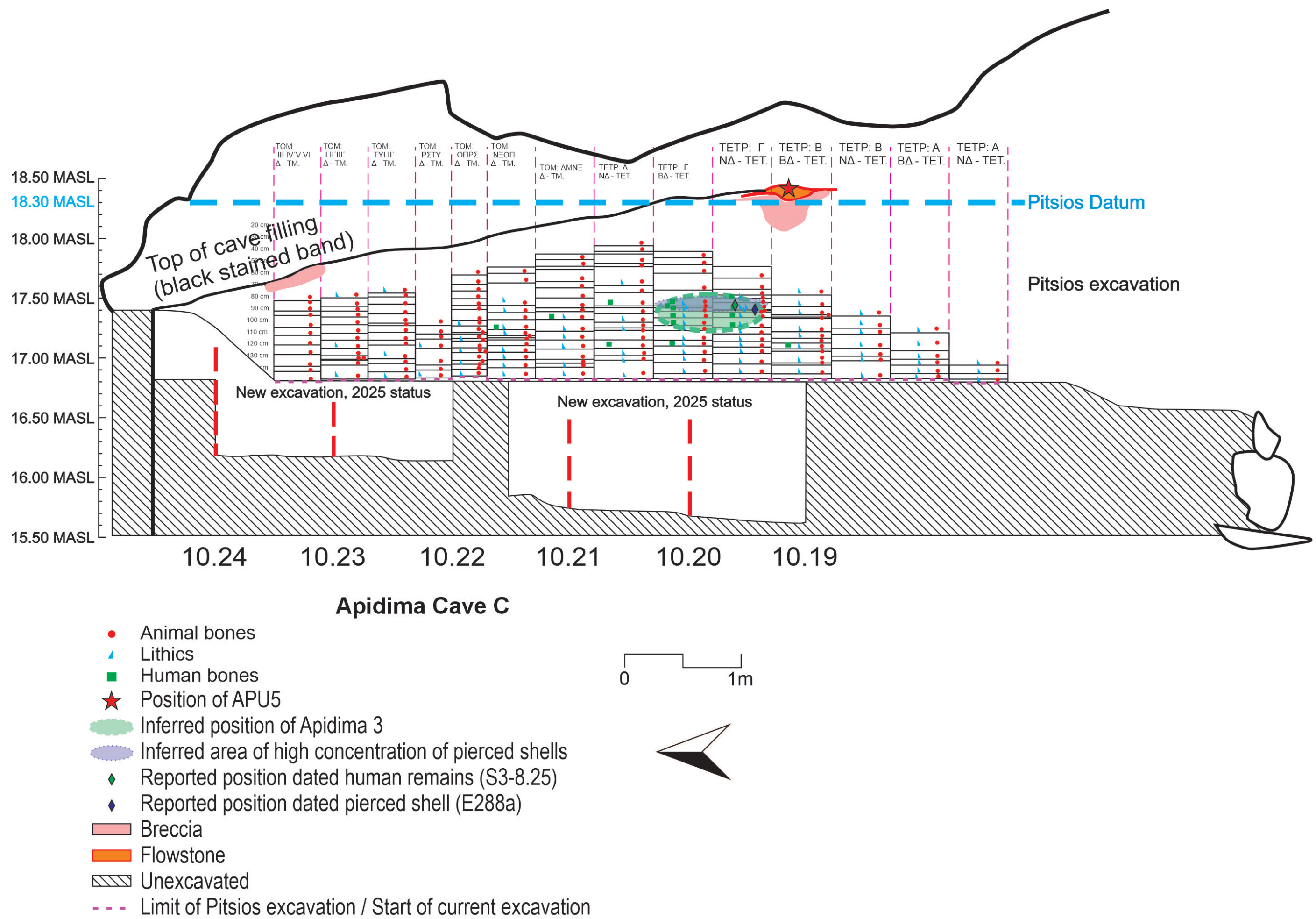

Figure 4. Schematic section drawing of the Pitsios excavation of Cave C, indicating the position of the Pitsios excavation datum (blue dashed line); the position of the travertine capping the original sediments; the location of sample APU5 (red star); the inferred location of the main accumulation of the human skeleton Apidima 3 (green ellipse) and other human bones, as shown in Pitsios and Liebhaber (1995: Figure 3), including the dated human bone S3-8.25 (Harvati et al. 2021); the inferred accumulation of the perforated T. neritea shells (purple ellipse) and position of the dated specimen E288.2; as well as the limits of the Pitios excavation and the current excavation (status 2025).

the condense layers to build isochrones (see Figure 6A; Table 1). The first isochron (n=8) yielded corrected ratios of $^{234}U/^{238}U$=1.37±0.2 and $^{230}Th/^{238}U$=0.359±0.027, corresponding to an age of 32.9±6.5 ka (Figure 6B, C). The second isochron (n=8) produced corrected ratios of $^{234}U/^{238}U$=1.31±0.16 and $^{230}Th/^{238}U$=0.376±0.039, corresponding an age of 36.5±7.1 ka (see Figure 6B, C). An error weighted mean age of 34.5±4.8 ka was calculated from the two isochron results.

Radiocarbon analysis: The dates produced by the samples and associated errors are reported in Table 2 and plotted in Figure 7. The marine shell dates are calibrated using the latest marine calibration curve (Marine20; Heaton et al. 2020), also corrected for a local reservoir (ΔR), which is the weighted mean of five values closest to the dated sites (CHRONOS marine reservoir database), as for marine carbonate correction, both a global (i.e, Marine20) and a local reservoir correction are required. We used a ΔR of -116±117 years, which is broadly comparable in magnitude to the value reported by Facorellis and Vardala-Theodorou (2015) of 148±40 years, calculated from charcoal-shell pairs from several archaeological sites across the Aegean.

The dated pierced shells from the Cave C collection provided ages of 21.9±0.11 ka BP, 21.4±0.1 ka BP, and 27.9±0.2 ka BP (ka BP=thousand years before 1950). When calibrated, these translate to dates of 25.8–25.0 ka cal BP for specimen E288.2 (VIE-1952); 25.4–24.5 ka cal BP for specimen E560 (VIE-1953), and 31.8–30.8 ka cal BP for specimen E507.2 (VIE-1954). Of these, precise stratigraphic information exists only for E288.2 (VIE-1952), which was recovered at an elevation of 93cm below datum according to tag in-

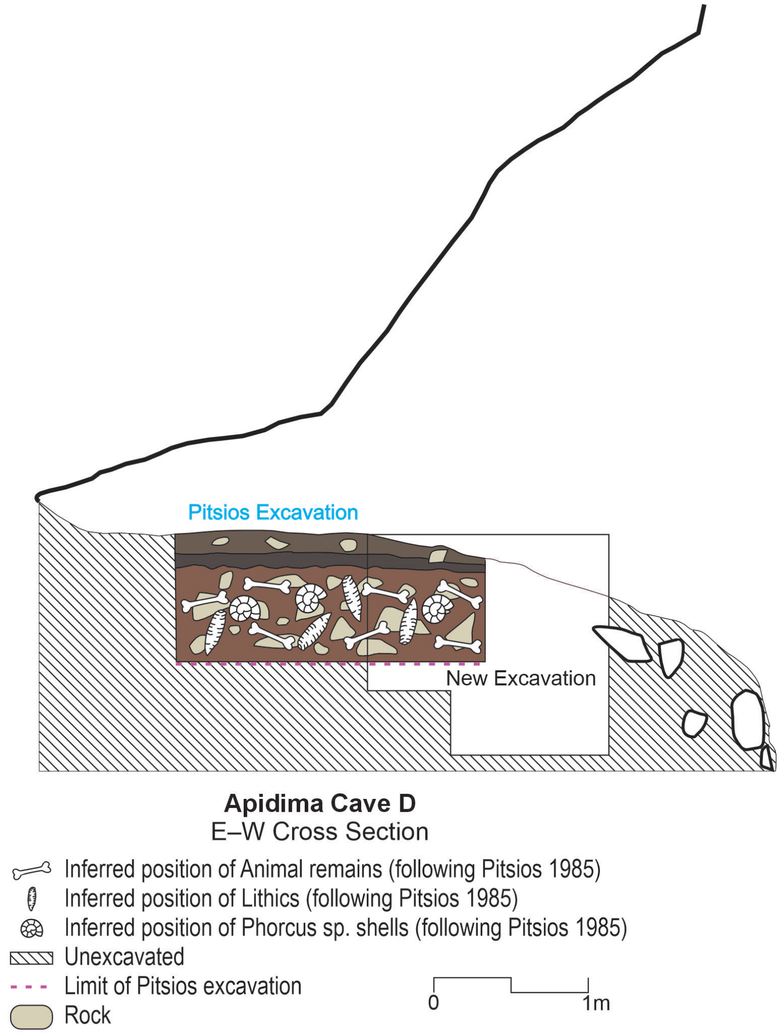

Figure 5. Schematic stratigraphy of the Pitsios excavation of Cave D, showing the mentioned three layers and the accumulation of finds including the inferred position of Phorcus *sp. shells dated here.*

formation, and near or among the accumulation of the Apidima 3 human skeleton.

The *Phorcus sp*. shells from Cave D yielded younger, and non-overlapping ages, to those of Cave C, ranging from 15.0 to 19.1 ka BP, which, when calibrated, range between 17.1–22.7 ka cal BP.

DISCUSSION

Here we conducted U-series and radiocarbon dating of samples from Apidima Caves C and D, with the goal of providing chronological constraints for the legacy assemblages excavated by T. Pitsios and his team at those sites in the 1980s. Since very limited information exists on the context of these collections, our results here should be interpreted as providing only a broad chronological context for these finds.

For Cave C, the U-series date of the APU5 sample yielded an age of 34.5±4.8 ka. Since speleothems are closed systems, all their U is present when they are formed, the age results represent their deposition age (in contrast to bone samples, which are an open system, and produce results which are minimum age estimates). As the sample derives from a travertine crust interpreted to cap the original sedimentary sequence of Cave C, the sediments excavated by Pitsios should be at least older than 29.7 ka, the minimum of this range (by subtracting the uncertainty from the calculated age). This upper limit is consistent with our recent attribution of the legacy lithic collection from Apidima Cave C as Protoaurignacian (Lombardo et al. 2026a [this issue]). However, only one of the perforated shell samples (E507.2 / VIE-1954) was older than the minimum age of the travertine crust, falling between 31.8–30.8 ka cal BP (E507.2 / VIE-1954). The dated legacy Cave C shells are also substantially younger than the proposed age range of ~42–39 ka for the Protoaurignacian elsewhere in Europe (e.g., Banks et al. 2013) and younger also than Aurignacian layers elsewhere in Greece (Klissoura: 32400±600 and 33150±120 ^{14}C yrs BP, Kuhn et al. 2010; Franchthi: 34980±220, 30580±160, and 29780±160 ^{14}C yrs BP, Douka et al. 2011, Perlès 1987; Kolominitsa: 33870±550 ^{14}C yrs BP, Darlas and Psathi 2016).

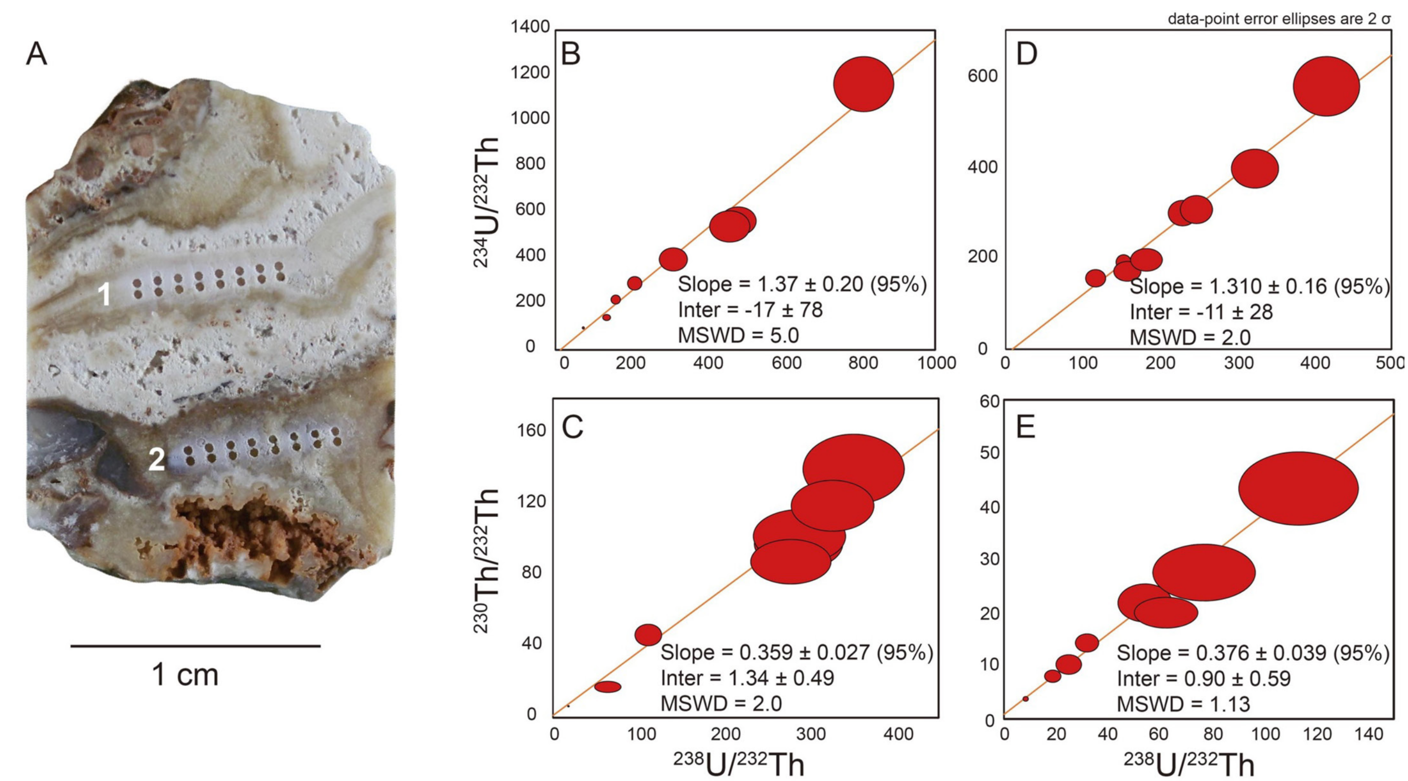

Figure 6. Sample APU5 with the laser ablated spots (A) and the Rosholt Type-II isochrones built with the LA U-series data obtained on the transect 1 (B, C) and the transect 2 (D, E).

TABLE 1. LA-MC-ICP-MS U-SERIES ANALYTICAL RESULTS OBTAINED ON SAMPLE APU5.

Transect	Spot 1			Spot 2		Age [ka]
	^{238}U [ppm]	($^{238}U/^{232}Th$)	($^{234}U/^{238}U$)	($^{230}Th/^{238}U$)	($^{230}Th/^{232}Th$)	
1	0.687±0.063	50±2	1.640±0.026	0.433±0.025	45.4±5.0	32.6±2.2
	0.285±0.025	139±10	1.500±0.034	0.509±0.030	4.6±0.3	44.0±3.4
	0.227±0.018	191±16	1.471±0.036	0.399±0.032	140.4±16.3	33.9±3.3
	0.179±0.013	817±67	1.428±0.036	0.342±0.031	97.5±12.0	29.4±3.1
	0.091±0.007	114±9	1.128±0.042	0.278±0.044	15.7±2.6	30.7±5.8
	0.107±0.009	474±40	1.178±0.042	0.356±0.036	101.9±12.5	38.8±4.9
	0.095±0.007	450±45	1.185±0.044	0.316±0.025	87.3±10.4	33.5±3.4
	0.165±0.012	296±31	1.306±0.033	0.366±0.027	119.4±11.9	35.3±3.3
2	0.115±0.011	109±11	1.376±0.045	0.508±0.037	3.2±0.4	49.0±4.8
	0.116±0.009	225±16	1.312±0.048	0.456±0.031	13.9±1.4	45.6±4.4
	0.130±0.011	417±36	1.385±0.050	0.404±0.035	21.5±3.0	36.9±4.1
	0.078±0.006	147±8	1.269±0.061	0.420±0.035	9.7±1.5	43.0±5.1
	0.085±0.007	244±18	1.244±0.054	0.444±0.039	7.5±1.0	47.2±5.8
	0.085±0.007	152±15	1.094±0.051	0.357±0.051	27.3±4.4	42.7±7.9
	0.078±0.006	322±26	1.225±0.050	0.381±0.040	43.3±5.7	40.1±5.5
	0.069±0.005	177±17	1.081±0.048	0.319±0.036	19.6±2.4	37.9±5.5

TABLE 2. RADIOCARBON RESULTS (RAW AND CALIBRATED) FROM SHELL REMAINS FROM THE LEGACY COLLECTIONS OF APIDIMA CAVES C AND D.

	Species	Lab code	$F^{14}C$	±	^{14}C age	±	Calibrated years BP			
							from	to	from	to
Cave C							68.2%		95.4%	
E560	*Tritia* sp.	VIE-1953	0.0689	0.0009	**21487**	**109**	25190	24740	25420	24490
E288.2	*Tritia* sp.	VIE-1952	0.0649	0.0009	**21971**	**117**	25680	25280	25840	25080
E507.2	*Tritia* sp.	VIE-1954	0.0309	0.0008	**27941**	**222**	31520	31050	31810	30860
Cave D										
Sample ID 1	*Phorcus* sp.	VIE-1955	0.1537	0.0011	**15045**	**55**	17750	17330	17940	17120
Sample ID 2	*Phorcus* sp.	VIE-1956	0.0925	0.0011	**19120**	**93**	22500	22120	22740	21950
Sample ID 3	*Phorcus* sp.	VIE-1957	0.1257	0.001	**16657**	**66**	19530	19130	19750	18930
Sample ID 4	*Phorcus* sp.	VIE-1958	0.1105	0.001	**17692**	**73**	20790	20410	20960	20190
Sample ID 5	*Phorcus* sp.	VIE-1959	0.1078	0.001	**17894**	**79**	21020	20590	21280	20420

This suggests that the potential shell beads dated here may not be associated with the legacy lithic assemblage attributed to the Protoaurignacian by Lombardo et al. (2026a [this issue]) and may have been intrusive to the original sequence. If we accept that the perforated shells were indeed personal ornaments associated with the Apidima 3 skeleton, as suggested by Mompheratou and Pitsios (1995) and potentially supported by the reported position of sample E288.2/VIE-1952, our results indicate that the burial was also potentially intrusive and not associated with the Protoaurignacian lithics. Rather, it could have derived from a Gravettian cultural context postdating the Protoaurignacian human presence at Apidima Cave C, but pre-dating the early Epigravettian documented by the legacy collection in Cave D (see below). This conclusion may also be supported by the limited information published by Mompherratou and Pitsios (1995), who mention only that the skeleton was found with 'an unusual stone knife' and a "natural piece of rock crystal" (see also Lomdardo et al. 2026a [this issue]), in contrast to the assumption by Darlas (1995), who suggested association between Aurignacian-like lithics and the Apidima 3 skeleton, a statement later also repeated by Pitsios (1999). The body proportions of Apidima 3 are consistent with a pre LGM cultural affiliation (Naumann et al. 2026 [this issue]), while the currently available Terminal Pleistocene direct date for the skeleton is a minimum U-series age on bone, which does not preclude such an attribution (Harvati et al. 2021). Ongoing combined U-series/ESR direct dating of the Apidima 3 human remains will help clarify this issue further, while the dating program for our new excavation of Cave C will shed further light on the early Upper Paleolithic and Protoaurignacian at the site.

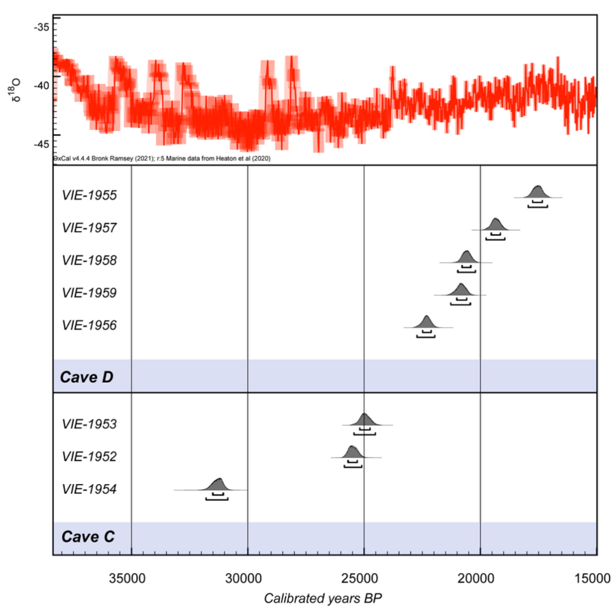

Figure 7. Calibrated ages of the new shell dates. Data shown in Table 2. The dates are calibrated using Marine20 (Heaton et al. 2020) and a local reservoir (see text for details). The NGRIP oxygen isotope record is plotted in red above the probability distribution functions (Bronk-Ramsey et al. 2014). The plot was produced using OxCal v4.4.

For Cave D we obtained five new dates from shell samples from the legacy collection excavated by Pitsios, ranging from 17.1–22.7 ka cal BP. Since we have no stratigraphic information on the original position of these specimens, their age range can only be considered as providing a broad temporal framework for the Cave D old excavation. This timeframe, however, is compatible with our recent assessment of the lithics from the Pitsios Cave D collection, attributed by Lombardo et al. (2026b [this issue]) to the early Epigravettian, but is younger than the perforated shells, and presumably the Apidima 3 skeleton, from Cave C. Ongoing new excavation of Cave D, including the layers below the Pitsios excavation, will help us assess whether an earlier Gravettian presence can be established, which might potentially be linked with the Apidima 3 skeleton in Cave C.

It is important to note that all shell determinations we report here fall clearly in some of the coldest climatic episodes of the Late Pleistocene (see also Chitoglou et al. 2026 [this issue]). For Cave C, VIE-1954 corresponds to the stadial conditions of GS-5 (Rasmussen et al. 2014) at the end of MIS 3, whereas the remaining two determinations from the site (VIE-1953 and VIE-1952) fall between ~24.5–25.8 ka cal BP, within the prolonged GS-3 at the onset of the LGM. For Cave D, the shell dates fall between 17.1–22.7 ka cal BP, and also coincide with the duration of the LGM. We may hypothesize that the substantially lower sea levels during these colder periods, reaching as much as -120m to -110m, exposed a coastal platform standing several hundred meters or more in front of the caves, thereby promoting the formation of rocky pools and intertidal habitats. *Phorcus* spp such as those found in Cave D are commonly associated with such types of intertidal rocky shores and are edible. These shells were therefore likely collected deliberately, either from sandy deposits, or from the newly exposed benthic zones. Lower sea levels persisted until about 21 ka BP and the onset of deglaciation. Thereafter, rising sea levels altered significantly the local coastline, which would eventually make access to the sites increasingly difficult.

CONCLUSIONS

In conclusion, the dating results reported place the three pierced shells from Cave C between ca. 24.5–31.8 ka cal BP, suggesting that they, and potentially also the Apidima 3 human skeleton, are younger than the majority of the Cave C legacy lithic assemblage recently attributed to the Protoaurignacian, and are likely intrusive to the original sediments. Our findings suggest that at least some of the pierced shells, and potentially also the human burial, from Apidima Cave C could instead derive from a later, potentially Gravettian context. However, this is only a tentative assessment that will be further tested with additional direct dating of the skeleton and from the new excavation in Cave C.

In contrast, the dates obtained from Cave D range between 17.1–22.7 ka cal BP, a timeframe that fits well with our early Epigravettian attribution of the lithic assemblage from the Pitsios Cave D excavation. These results highlight the importance of the Apidima Caves not only for the Middle Pleistocene of Greece and Southern Europe as a whole (see Harvati 2026; Harvati et al. 2019) but also for the study of Upper Paleolithic human populations in Greece, whose presence is attested in several sites across the southeastern Peloponnese (e.g., Tourloukis and Harvati 2018). Ongoing excavation and additional dating analyses from both sites are expected to shed further light on the Upper Paleolithic hunter gatherers of Greece and the southern Balkans.

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DATA AVAILABILITY STATEMENT

All data necessary to evaluate this work are included in the paper.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

KH: Conceptualization, Investigation, Resources, Project administration, Funding acquisition, Writing- Original draft; **KD**: Formal analysis, Investigation, Writing- Review & Editing; **QS**: Formal analysis, Investigation, Writing - Review & Editing; **RG**: Formal analysis, Investigation, Writing - Review & Editing; **NT:** Investigation, Writing - Review & Editing; **VGG:** Resources, Writing - Review & Editing; **KE:** Resources, Writing - Review & Editing; **VT**: Writing - Review & Editing; **PK**: Investigation, Writing - Review & Editing.

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