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Direct radiocarbon dating reveals medieval reuse at the prehistoric site of Grotta Romanelli (Castro, Apulia, Italy)

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Summary - *Grotta Romanelli has long been recognised as one of the most important prehistoric sites in the Mediterranean, preserving a rich assemblage of lithic artefacts, faunal remains, and parietal and mobiliary art, mostly dating to the late Middle and Late Pleistocene. In contrast, human remains recovered from the cave have remained poorly understood, particularly because the chronology of the three best-preserved individuals, excavated between 1900 and 1904, has never been directly radiocarbon dated. Based on stratigraphic evidence, P.E. Stasi referred them to prehistoric times, but this attribution has been questioned by several scholars. Here, we present new AMS radiocarbon dates obtained from these individuals, one adult and two infants. Our results demonstrate that the three burials belong to previously unrecognised phases of medieval reuse of the site. The adult individual dates to the fourteenth to early fifteenth century AD (1302–1369 and 1379–1411 cal AD, 95.4% probability), whereas the two infants date to the fifteenth century AD (1423–1455 and 1435–1489 cal AD, 95.4% probability). This finding highlights the importance of reassessing old archaeological collections using modern analytical approaches. The chronological ranges broadly overlap with periods of recurrent plague outbreaks in southern Italy, but any specific association between the burials and epidemic mortality needs further investigation.*

Keywords - *AMS radiocarbon dating, Medieval burials, Geoarchaeology, Stratigraphy, Bioanthropology, History of science.*

Introduction

Archaeological cave sites often preserve exceptionally long records of environmental change and human activity, sometimes spanning hundreds of thousands of years. Because of this long-term accumulation of deposits, caves frequently undergo multiple phases of use and reuse across different historical periods. Distinguishing between these episodes can

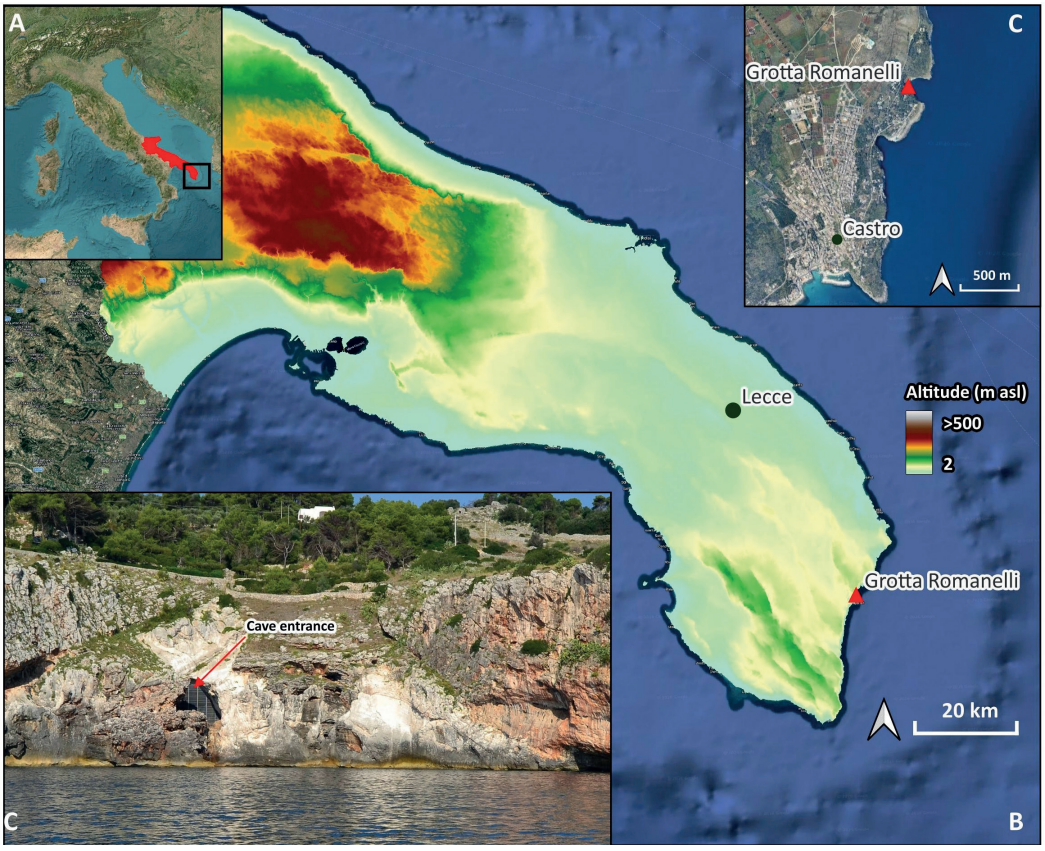

***Fig. 1** - Geographic setting of Grotta Romanelli. A) Location of Grotta Romanelli near Castro, Apulia. The base map was modified from "Italy map with regions.svg" (Wikimedia Commons, public domain). B) Digital elevation model of Apulia derived from TINITALY/1.1 (Tarquini et al. 2023), distributed under the Creative Commons Attribution 4.0 International licence, and processed using QGIS 3.16.7. C) Satellite view of the Salentine Peninsula based on Google Satellite imagery, accessed through the QuickMapServices plugin and processed using QGIS 3.16.7. Imagery © Google and third-party imagery providers; the original attribution is retained in the figure. The location of Grotta Romanelli was obtained from the Catasto delle Grotte e delle Cavità Artificiali della Regione Puglia. D) View of Romanelli Bay from the sea, showing the location of the cave entrance. Maps and photograph by Luca Forti.*

be challenging, particularly at sites that were excavated during the early development of archaeological research, when the recording of stratigraphic information was less systematic. Therefore, the chronology of materials recovered during early excavations may occasionally be misattributed, highlighting the importance of reassessing the legacy of historical collections with modern analytical techniques.

Grotta Romanelli, located along the Adriatic coast of the Salentine Peninsula, near Castro (Apulia, southern Italy, Fig. 1), is one of the most important prehistoric cave sites in the Mediterranean. Since its discovery in the early twentieth century, the cave has yielded a rich assemblage of lithic industries, vertebrate fauna, mobiliary and parietal art, and human skeletal remains (Blanc 1920). Grotta Romanelli has long served as a reference site for Quaternary archaeology, palaeontology, and palaeoenvironmental reconstruction in southern Europe (Sardella et al. 2019; Giustini et al. 2018).

Recent geoarchaeological and stratigraphic investigations have significantly revised the chronology of the cave deposits, demonstrating that the sedimentary sequence records environmental and depositional processes from the late Middle Pleistocene to the Holocene (Pieruccini et al. 2022). Despite the extensive research conducted at the site, however, several human skeletal remains recovered during the earliest excavations remain poorly documented, and their chronology has never been verified through direct dating (Alciati et al. 2005; Mecozzi et al. 2022).

The first systematic investigations at Grotta Romanelli were conducted between 1900 and 1904 by Paolo Emilio Stasi, a local naturalist and painter, in collaboration with the palaeontologist Ettore Regàlia, who was responsible for the study of the fossil fauna. These excavations revealed a substantial sedimentary sequence rich in lithic artefacts, faunal remains, and human remains, establishing the site as a key reference for Quaternary archaeology in southern Italy and, more broadly, in southern Europe (Stasi and Regalia 1904). However, the field documentation produced during this early phase was fragmentary and lacked the stratigraphic precision required by modern standards. Among the discoveries by Paolo Emilio Stasi (Stasi and Regalia 1904) were three inhumations containing one complete adult skeleton and two partially preserved infant skeletons. The burials were historically attributed to the prehistoric phases of the site, largely based on their presumed stratigraphic position. However, the absence of detailed excavation records and the lack of absolute dating have long prevented a secure chronological attribution.

Based on the stratigraphic position of the finds within the so-called "Terre Brune" and their association with hearths containing Pleistocene fauna, including the great auk (*Pinguinus impennis*) (Blanc 1928), Stasi and Regàlia initially attributed the three burials, discovered at a depth of 1.20 m from the floor level for the adult, and 1 m for the infants, to the Late Upper Palaeolithic (Stasi and Regalia 1904). An attribution to the Palaeolithic seemed reasonable to Stasi and Regàlia (Regalia and Stasi 1905) based on the faunal association, but their interpretation was strongly challenged by Luigi Pigorini, one of the leading figures in Italian palaethnology, who argued that no compelling evidence supported a Palaeolithic human occupation of Grotta Romanelli, including the interpretation of the burials (Pigorini 1904). Pigorini instead interpreted the remains as the result of stratigraphic disturbance and grave intrusion, suggesting a later, possibly Neolithic, chronology and pointing to the absence of grave goods, which prevented a more precise cultural attribution. Notably, the complete absence of grave goods further hampered any chronological interpretation.

Despite the importance of the site, the human assemblage from Grotta Romanelli has only been partially investigated. The available documentation is fragmentary and concerns only a portion of the recovered remains. Among the specimens listed in the Catalogue of Italian fossil human remains from the Palaeolithic to the Mesolithic (Alciati et al. 2005) as Romanelli 1–13, the three individuals analysed in the present study correspond to Romanelli 1–3 and were only briefly described in the original reports by Stasi. The remaining specimens, Romanelli 4–13, currently preserved at IsIPU (Istituto Italiano di Paleontologia Umana), were later examined by Fabbri (Fabbri 1987), who also reported the presence of an additional 84 unlabelled human bone fragments. Although both the catalogue and Fabbri's study document the existence of these materials, no detailed description or comprehensive analysis of the unlabelled fragments has ever been published. Furthermore, materials recovered during later twentieth-century excavations were partly lost or never published (*e.g.*, Alciati et al. 2005; Blanc 1920; Blanc 1928; Lazzari 1955). The dispersal of the skeletal collection between IsIPU, the University of Naples, and possibly other repositories likely further hindered a systematic study of the human odontoskeletal record. Therefore, the human remains from Grotta Romanelli have received far less analytical attention than other categories of archaeological evidence from the site.

From 1914, Gian Alberto Blanc introduced physico-chemical and stratigraphic methods to the study of Grotta Romanelli's deposits, substantially refining the site's chronological framework (Blanc 1920). His approach, however, devoted limited attention to the human specimens, whose stratigraphic attribution therefore remained largely unaddressed (see Supplementary Materials for further historical detail on Blanc's work at the site).

Methods

Study materials

The human specimens analysed in this study belong to the Stasi collection, currently housed in the Museum of Anthropology of the University of Naples Federico II. The collection was acquired from Paolo Emilio Stasi in 1914 through the efforts of Vincenzo Giuffrida Ruggeri, then Professor of Anthropology at the University of Naples, and comprises the three individuals examined here (Romanelli 1, 2 and 3), together with further archaeological and anthropological materials from Grotta Romanelli. Excavated by Stasi between 1900 and 1904 (Stasi and Regalia 1904), the three individuals - Romanelli 1, Romanelli 2 and Romanelli 3 - were historically attributed to the Late Upper Palaeolithic on the basis of their stratigraphic position (Alciati et al. 2005; Fabbri 1987). Following periods of dispersal and relocation during the twentieth century, the collection was rediscovered and reorganised in the 1990s, enabling its renewed study and, in this case, direct radiocarbon dating. Further historical information on the collection is provided in the Supplementary Materials.

Spatial reconstruction of burial locations

The position of the burials (Fig. 2) was reconstructed by overlaying the original findspots recorded in the published planimetric view of the cave (Stasi and Regalia 1904), which indicated the location of the finds and the trenches together with their length and depth, onto the modern plan of the cave obtained during our excavations, using the few benchmarks still identifiable today (*e.g.*, the rockfall). This procedure allows a decimetric precision to be achieved for some features, but the plotted positions should be regarded as approximate rather than exact, and some degree of positional uncertainty cannot be excluded.

Basic osteological assessment was carried out following established bioarchaeological protocols (Buikstra and Ubelaker 1994; White et al. 2011). Each specimen was examined macroscopically to determine skeletal element representation and preservation state. Age-at-death estimation was performed using morphological and developmental criteria. For the adult individual, dental wear (Lovejoy 1985), degenerative changes of the pubic symphysis (Todd 1921), the sternal end of the ribs (Işcan and Loth 1986), and vertebral ring epiphyseal fusion (Burns 2015) were considered. For the subadult individuals, age-at-death was estimated primarily from dental development following AlQahtani et al. (2010) and Ubelaker (1989) Long-bone measurements, when preserved, were used as an independent validation of the dental estimate according to tables reported in (Scheuer and Black 2000). Reported age ranges reflect the uncertainty associated with the dental standards and their consistency with the osteological evidence. Biological sex estimation was performed on the adult individual based on sexually dimorphic traits of the pelvis and skull (White et al. 2011).

Radiocarbon dating

Radiocarbon dating was performed at the CEDAD laboratory (Centro di Fisica Applicata, Datazione e Diagnostica) at the University of Salento using Accelerator Mass Spectrometry (AMS) (Calcagnile et al. 2019).

Prior to analysis, bone samples underwent mechanical cleaning and chemical pretreatment in order to remove contaminants and isolate collagen. The macro-contaminants present in the samples were identified under an optical microscope and removed mechanically. A chemical

treatment, modified from Longin's method (Longin 1971), was then applied, involving alternating acid-alkali-acid treatments to remove contaminants and the inorganic component (hydroxyapatite). To this end, the samples were ground to a powder (<0.5mm), treated with acetone, demineralised with 1M hydrochloric acid, and the collagen was extracted as hydrolysed gelatin in water at pH 3 and 90°C, then filtered (0.45µm).

The quality and preservation state of the selected samples were assessed by considering their collagen content and atomic C/N ratio. Specifically, the collagen content ranged from 4 to 11 wt%, well above the threshold (1%) reported in the literature for well-preserved collagen. Similarly, the C/N atomic ratio ranged from 3.0 to 3.2, well within the range (2.9-3.2) considered standard for modern animal and human bones, as well as for well-preserved archaeological samples (Van Klinken 1999). Stable carbon and nitrogen isotopic ratios were measured at CEDAD by IRMS (Isotope Ratio Mass Spectrometry) by using the Mod. Delta V Plus IRMS system by Thermo.

The extracted gelatine was then combusted in quartz tubes sealed with copper oxide and silver wool at 900°C to produce CO_2 and subsequently reduced to graphite using H_2 and iron powder as a catalyst (D'Elia et al. 2004). The resulting graphite was pressed into cathodes and analysed using CEDAD's high-resolution AMS mass spectrometer, measuring the $^{14}C/^{12}C$ and $^{13}C/^{12}C$ isotope ratios relative to international standards (NIST oxalic acid and IAEAC6 sucrose), and corrected for isotopic fractionation ($\delta^{13}C$) and for instrumental and preparative background (Hajdas et al. 2021; Stuiver and Polach 1977). The quantity of graphite obtained (>1mg per sample) proved optimal for radiocarbon measurements. Radiocarbon ages were calibrated using OxCal v4.4 and the IntCal20 atmospheric calibration curve (Reimer et al. 2020). The carbon and nitrogen stable isotope values are consistent with a predominantly terrestrial diet and indicate that a significant marine reservoir effect on the radiocarbon ages is unlikely.

Results

During the 2016-2025 field campaigns, the stratigraphy of the cave was revised, and the infilled deposits were mapped in detail. The reconstruction of the original stratigraphic context of the burials largely depends on the limited documentation provided by Stasi (Blanc 1920; Pigorini 1904; Quagliati 1936; Stasi and Regalia 1904). According to the available records, the adult individual was found in the external part of the cave deposit, on top of the slope debris that had accumulated near the cave entrance and was dipping seaward (Stasi and Regalia 1904). The two infants were reported by Stasi as buried in a seated position within the trenches excavated during his attempts to access the cave interior (Stasi and Regalia 1904); this original observation cannot be independently verified and is reported here as a historical record rather than a confirmed archaeological reconstruction. The spatial position of the three burials within the cave (Fig. 2) was reconstructed from archival sources, as detailed in the Methods.

This spatial distribution only suggests that the burials were likely younger than the part of the deposit deeper than 1m, with no clear association with the prehistoric sedimentary sequence preserved within the cave. As early as the mid-twentieth century, some scholars raised concerns regarding the integrity of the stratigraphy excavated by Stasi (Quagliati 1936). Disturbances caused by earlier explorations, later excavations and possible clandestine excavations may have affected the uppermost deposits (Lazzari 1955).

Recent geoarchaeological investigations have further highlighted the complexity of the sedimentary processes within the cave. The uppermost units of the succession, including the so-called "Terre Brune", have been shown to reflect episodes of sediment reworking and slope-driven depositional processes that occurred during the Late Pleistocene and Holocene (Pieruccini et al. 2022; Tema et al. 2025). These observations underscore the importance of verifying the chronological attribution of materials recovered from the uppermost portions of the cave deposits.

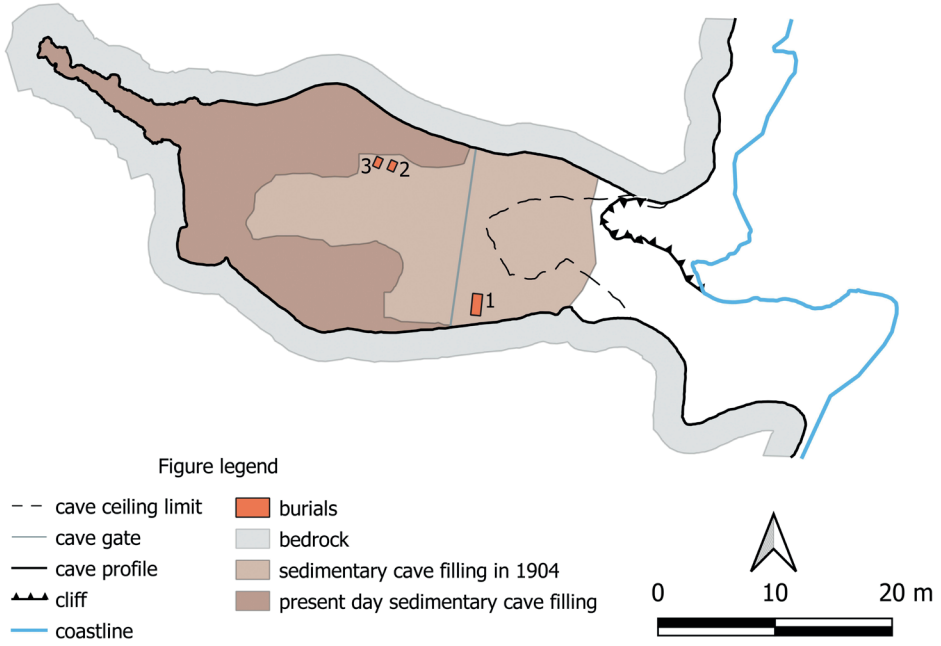

***Fig. 2** - Plan of Grotta Romanelli showing the approximate location of the burials discovered in 1904, reconstructed from archival records (see Methods). 1 = adult burial (Romanelli 1); 2 = subadult burial (Romanelli 2); 3 = subadult burial (Romanelli 3) (Illustration by Giuseppe Lembo).*

Osteological analysis

Romanelli 1

Romanelli 1 is an adult individual represented by a nearly complete skeleton. All anatomical regions are well-preserved, exhibiting minimal taphonomic degradation, limited to superficial surface erosion of both cranial and postcranial bones, with no evidence of traumatic or pathological alterations. The cranium is nearly complete and well preserved (Fig. 3). Within the postcranial skeleton, only the scapulae are fragmentary, and a single thoracic vertebra is absent. The majority of the teeth are preserved in situ, except the upper right canine and third molar and the upper left second molar, lost *post mortem*.

The sexually dimorphic cranial features, such as the large and well-developed mastoid process and nuchal crest, the robust mandible showing a pronounced chin and a vertical ramus, together with a narrow pelvis, allowed the sex of the Romanelli 1 individual to be estimated as male (White et al. 2011). Regarding age-at-death estimation, the combined analysis of the pubic symphysis (stage VII, Todd 1921), the modification of the sternal rib ends (Işcan and Loth 1986), and dental wear pattern (stage F, Lovejoy 1985) yielded an estimated age range of 30–40 years. The epiphyseal ring, however, showed complete fusion without any degenerative changes typically associated with a more advanced age (Burns 2015), thus pointing to the lower range of the interval.

The biological profile and the inventory of preserved anatomical districts are consistent with the description provided in the Catalogue of Italian Fossil Human Remains from the Palaeolithic to the Mesolithic (Alciati et al. 2005). However, while the present anthropological analysis provides a specific age range, the previous report classified the individual generically as an adult, without providing further age estimation.

***Fig. 3** - Cranium and mandible of Romanelli 1 (adult, estimated as male, 30–40 years), frontal and right lateral views. The skull is well preserved and retains most of its anatomical features. (Museum of Anthropology, University of Naples Federico II). Scale bar: 5cm.*

Romanelli 2

Romanelli 2 is an incomplete subadult individual, represented by the cranium lacking the facial bones and part of the zygomatic processes, the mandible, a fragmentary thorax, and some elements pertaining to the upper limbs. The pelvic girdle and lower limbs are absent, as also reported in previous descriptions (Alciati et al. 2005; Stasi and Regalia 1904).

Age-at-death has been estimated at 9 ± 3 months, as indicated by the dental development (AlQahtani et al. 2010; Ubelaker 1989) and by the length of the radius (Tab. 1). The preserved radius has a maximum diaphyseal length of 71 mm. Comparison with published growth standards indicates an osteological age broadly consistent with late infancy, corresponding to 6–12 months according to Gindhart (1973) and approximately 6 months according to Maresh (1970). Because these reference standards are sex-specific and the sex of Romanelli 2 cannot be determined, the osteological estimate was considered supportive to the dental age estimation. The final age-at-death estimate, therefore, relied primarily on dental development, and the age range reflects the uncertainty associated with the dental standards.

Romanelli 3

Romanelli 3 is an incomplete subadult individual, represented by the cranium lacking the frontal bone, the mandible, a fragmentary thorax, the left humerus, and some elements of the lower limbs. Pelvic girdles, right upper limb, left forearm, and right femur are missing. Unlike what was previously described (Alciati et al. 2005; Stasi and Regalia 1904), several elements of the lower limbs are present .

Age-at-death was estimated primarily from dental development following AlQahtani et al. (2010) and Ubelaker (1989). The preserved long bones were used as an independent osteological assessment: the maximum lengths of the left humerus (100 mm), left femur (127 mm), and right tibia (105 mm) correspond to an age of approximately 1 year according to Maresh (1970), and were consistent with the dental development estimate interval. The final age-at-death was therefore assigned as 18 ± 6 months (Tab. 1), and the age range reflects the uncertainty associated with the dental standards.

Tab. 1 - Osteological and dental indicators used for age-at-death estimation of the Romanelli subadults. Dental development was considered the primary age indicator. di1: deciduous first incisor; di2: deciduous second incisor; dc: deciduous canine; dm1: deciduous first molar; dm2: deciduous second molar; M1: permanent first molar. R = root; Ri = root initiation; CrC = crown complete; CoC = cusp outline complete.

INDIVIDUAL	INDICATOR	OBSERVATION	REFERENCE	AGE ESTIMATE
Romanelli 2	Dental development	di1 R 3/4	AlQahtani et al. (2010); Ubelaker (1989)	**9 ± 3 months**
		di2 R 1/2		
		dc CrC		
		dm1 R 1/4		
		dm2 CrC		
		M1 CoC		
Romanelli 2	Right radius	Maximum length: 71 mm	Maresh (1970); Gindhart (1973)	~9 months
Romanelli 3	Dental development	di1 R 3/4	AlQahtani et al. (2010); Ubelaker (1989)	**18 ± 6 months**
		di2 R 3/4		
		dc Ri		
		dm1 R 1/2		
		dm2 Ri		
		M1 CoC		
Romanelli 3	Left humerus	Maximum length: 100 mm	Maresh (1970)	~12 months
Romanelli 3	Left femur	Maximum length: 127 mm	Maresh (1970)	~12 months
Romanelli 3	Right tibia	Maximum length: 105 mm	Maresh (1970)	~12 months

Radiocarbon dating

Rib fragments from all three individuals were selected for radiocarbon dating. Bone samples suitable for collagen extraction were selected from well-preserved cortical portions. All three samples yielded reliable results (Tab. 2, Fig. 4): sample LTL34760, corresponding to the male adult Romanelli 1, provided calibrated intervals of 1302–1369 and 1379–1411 cal AD (95.4% probability); sample LTL34758, corresponding to the infant Romanelli 2, provided a calibrated date of 1423–1455 cal AD (95.4% probability); sample LTL34759, corresponding to the infant Romanelli 3, provided a calibrated date of 1435–1489 cal AD (95.4% probability). These results establish a chronological framework spanning the fourteenth and fifteenth centuries AD. The overlapping ranges of Romanelli 2 and Romanelli 3 indicate chronological compatibility but do not by themselves demonstrate that the two individuals were buried in the same event.

Discussion

The AMS dates presented here unequivocally demonstrate that the three burials from Grotta

***Tab. 2** - Samples analysed, collagen quality indicators, stable isotope values, conventional radiocarbon ages, and calibrated date ranges.*

SAMPLE	CEDAD LAB CODE	C/N	$\delta^{13}C$ (‰ VPDB) (±0.1)	$\delta^{15}N$ (‰ AIR) (±0.1)	RADIOCARBON DATE (BP)	CALIBRATED AGE RANGE (CAL AD)
ROMANELLI 1	LTL34760	3.2	-21.9	10.2	592±30	1302 – 1369 (69.6%) 1379 – 1411 (25.8%)
ROMANELLI 2	LTL34758	3.0	-21.2	9.6	461±20	1423 - 1455 (95.4%)
ROMANELLI 3	LTL34759	3.0	-22.0	9.8	422±20	1435 - 1489 (95.4%)

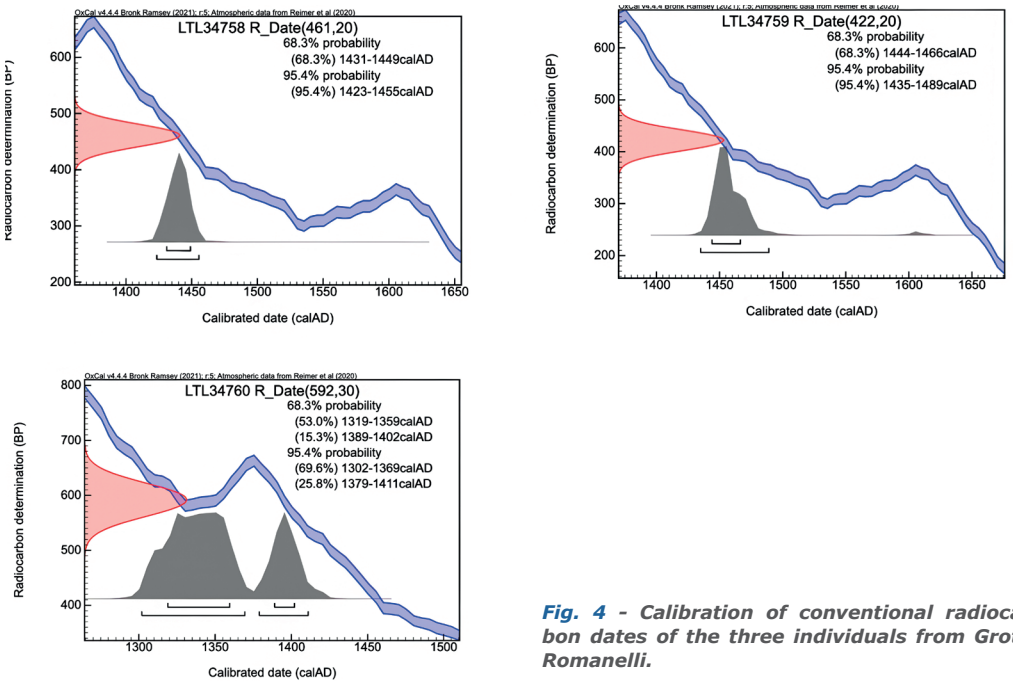

***Fig. 4** - Calibration of conventional radiocarbon dates of the three individuals from Grotta Romanelli.*

Romanelli date to the fourteenth and fifteenth centuries AD, overturning the previous attribution to the Late Upper Palaeolithic that had persisted in catalogues and parts of the literature despite longstanding reservations, first raised by Pigorini over a century ago (Pigorini 1904; Alciati et al. 2005; Stasi and Regalia 1904). These results extend the documented human use of the cave well beyond its known prehistoric occupation, adding a previously unrecognised historical

dimension to one of the most studied archaeological sites in the Mediterranean (Pieruccini et al. 2022). According to published lists, the excavations conducted by Stasi and Blanc yielded human remains attributable to at least 15 individuals (Fabbri 1987) although the three examined in the present study are the only ones clearly associated with individual, documented burials. It should be emphasised that the new AMS dates pertain exclusively to Romanelli 1–3, the only individuals explicitly described as deriving from discrete burials in the surviving historical documentation. The chronological attribution of the remaining human remains from Grotta Romanelli, whose depositional context is not clearly established, cannot be inferred from the present results. Whether these specimens are associated with the Palaeolithic occupation of the site or with later frequentations remains an open question and will be the subject of future dedicated study by the authors. The identification of medieval burials indicates that Grotta Romanelli continued to form part of the cultural landscape of the Salento region long after the end of its prehistoric occupation and calls for a reassessment of those human remains from the site whose chronological attribution has never been directly verified.

The original attribution of these individuals to the Palaeolithic most likely reflects the methodological limitations of early twentieth-century excavation practices, when contextual documentation and stratigraphic information were less rigorous than modern archaeological standards. Discrepancies between our observations and the early excavation reports further illustrate these limitations: Romanelli 3, for instance, was described as lacking the lower limbs, which are instead preserved in the museum collection, while Stasi's vivid observation that the children's remains possessed a peculiar colour 'white, like river gravel' (Stasi and Regalia 1904) hints at taphonomic processes that were not systematically investigated at the time. Arguably, the debate framed exclusively in terms of a Palaeolithic versus Neolithic attribution diverted attention from the possibility of a substantially different chronological framework, an ambiguity the present results resolve definitively.

It should be noted that human remains genuinely associated with the Palaeolithic occupation of the cave have also been identified. Borić et al. (2024) report the direct dating of a human rib fragment recovered among faunal remains at Grotta Romanelli and identified through Zooarchaeology by Mass Spectrometry (ZooMS), which yielded a calibrated age of 13,225–12,765 cal BP (95% confidence interval). Mecozzi et al. (2022) published a distal human hand phalanx, recovered during the 2019 excavation campaign, from levels dated between 13,886–13,589 and 11,319–11,188 cal BP. Along with the broader archaeological evidence for Palaeolithic occupation of the cave (Mecozzi et al. 2022; Muttillo et al. 2025; Piperno 1974; Sigari et al. 2021), the identification of medieval burials highlights the long-term reuse and recurrent frequentation of cave environments, a phenomenon widely documented across Europe and the Mediterranean basin (Urdiales Viedma and Maccarone 2011; Bergsvik and Dowd 2018). Grotta Romanelli should therefore no longer be regarded as an exclusively prehistoric site, but rather as a place characterised by a complex, multi-phase occupational history spanning multiple cultural periods.

The chronological range of the three burials spans more than one phase in the medieval history of Castro and should not be assigned uniformly to a single historical context. Romanelli 1, dating to the fourteenth and early fifteenth centuries AD, falls broadly within the Angevin period (Phase X of the site's occupation sequence) (D'Andria 2020), as attested by the archaeological structures excavated at the Capanne site and dated to the fourteenth century (D'Andria 2020). Romanelli 2 and Romanelli 3, dating to the fifteenth century AD, correspond to a later phase during which Castro was connected to wider Adriatic exchange networks, some of which have been implicated in plague transmission (Yue et al. 2017). The 1480 Ottoman assault on nearby Otranto and the subsequent fortification of Castro Castle fall only within the latest part of Romanelli 3's chronological range and are incompatible with the dates of Romanelli 1 and Romanelli 2; this event should therefore not be treated as a general historical

explanation for the burials, but at most as a possible context for the latest of the three individuals, one that future bioarchaeological and historical investigation may help to clarify.

The chronological range of the burials overlaps with a period of severe demographic crisis in Europe, including recurrent outbreaks of plague (Green 2015), which we consider here as one of several possible explanations for the burials' informal character, to be weighed alongside other scenarios. The unusual burial contexts are not themselves diagnostic of epidemic mortality but are consistent with hurried burial practices documented in a range of crisis contexts, including plague episodes across medieval Europe. A relevant parallel is offered by the emergency burials of San Leonardo di Siponto, broadly contemporaneous, where biomolecular analyses identified *Yersinia pestis* (Raele et al. 2021); the coins recovered with those individuals appear to have been left on the bodies rather than deliberately placed as grave goods, plausibly reflecting a reluctance to handle the deceased, a pattern consistent with, rather than contrary to, plague-related mortality.

Targeted ancient DNA and isotopic analyses of the Grotta Romanelli individuals would allow this hypothesis to be tested directly. Future work will focus on the direct dating of the remaining human remains from Grotta Romanelli, together with ancient DNA and stable and radiogenic isotope analyses of Romanelli 1–3, to clarify the biological profile, geographic origin, and possible cause of death of the three individuals presented here. These results also call for a reconsideration of the Stasi collection as a whole: never publicly exhibited, it remains largely inaccessible to researchers and the public alike. Given that these are human remains, we would argue that any future museum display should balance scientific accessibility with due ethical care.

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Author contributions

RS, LB, GM and AN conceived the project; RS, MN, IM, AI, GM and AN conceived the paper outline; LC, DEM, GC, and GQ performed the analyses; RS, MN, IM, PP, AI, GM, AN wrote the original draft; RS, IM, PP, MN, LF, FB, GL, compiled and interpreted the archival documents and field data; GL, LF prepared the figures; AN, LB, AG, GM performed the bioanthropological analysis. All authors read, edited and approved the final manuscript.

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