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AMS ^{14}C dating at Can Ferrerons, a Roman octagonal building in Premià de Mar, Barcelona

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ABSTRACT

A singular Roman dwelling, octagonal in ground-plan, was excavated in the year 2000, in Premià de Mar. It is a freestanding pavilion within a larger settlement called Gran Via-Can Ferrerons. It was not possible to date it archaeologically because the basement trenches did not contain any significant dating artefacts. Archaeological research undertaken into the architectural typology of the monument led us to the hypothesis that the structure is to be interpreted as late Roman luxury domestic housing. It was decided to use AMS ^{14}C dating of the mortar in the masonry. This procedure dates the hardening of the carbonate binder in the mortar, which is the actual time of construction. We present the results of three analyses of mortar samples taken from the walls of the building. Radiocarbon dates coincide with the assumed architectural typology date, the date of the strata excavated at the site, and the date of the construction technique. These matches support the validity of the results (5th and 6th century CE).

1. Introduction

The octagonal Roman building of Can Ferrerons, in Premià de Mar (Barcelona) was discovered in 2000 and was excavated until 2008 (Fig. 1). The excavation has not been able to date its construction because the basement trenches in the building did not contain any significant dating artefacts (Bosch et al., 2005; Coll, 2009a, b; Font, 2013). Archaeological strata of soils, use and abandonment of the building have been dated to the 5th and 6th centuries CE. However, there were artefacts in them dated between the 1st and 6th centuries CE because the building was constructed in a site with a long history.

The peremptory need for establishing the building construction date follows from its importance. Can Ferrerons has a unique architecture, octagonal in ground-plan, with four large rooms, including a bath suite of linear development. It is also well preserved with walls up to 3 m in height, thanks to its robust construction. The correct interpretation of such a singular dwelling requires an accurate date. Our research on the use of the octagonal layouts in Roman residential buildings has revealed examples from Republican times (509–27 BCE) until late Antiquity (CE 284–714) as explained below. Although in the late Roman Empire there are many more examples to be found and seem to point to its use as dining suite. Because of this it is important to establish if the building was constructed in the late empire and fits to this more usual use or if it was constructed in another time and therefore we have to think about alternative concepts.

In this paper, we present the results of AMS ^{14}C dating of three mortar samples taken from the walls of the octagonal building. The interpretation and reliability of the dating results will be discussed as well as the implications for the chronology of the monument.

2. Can Ferrerons

2.1. Archaeological framework

Can Ferrerons is a freestanding pavilion of 710 m^2 within a larger settlement called Gran Via-Can Ferrerons covering an area of 5.5 ha (Coll, 2004) (Fig. 1). It is located on the coast, between the beach and (200 m away from it) the Roman road Via Augusta. It is in the town of Premià de Mar, 20 km north of Barcelona.

We only know about some small portions of this extensive site as can be seen in Fig. 1 (Barral, 1978; Prevosti, 1981; Coll, 2004; Bosch et al., 2005). The urban environment does not allow extensive excavations but what we discovered suggests a significant settlement with a substantial industrial core, normally interpreted as a villa. The rich Roman mosaic (Fig. 1B, 1) supports this latter classification. The presence of different workshops also supports the interpretation of a villa.

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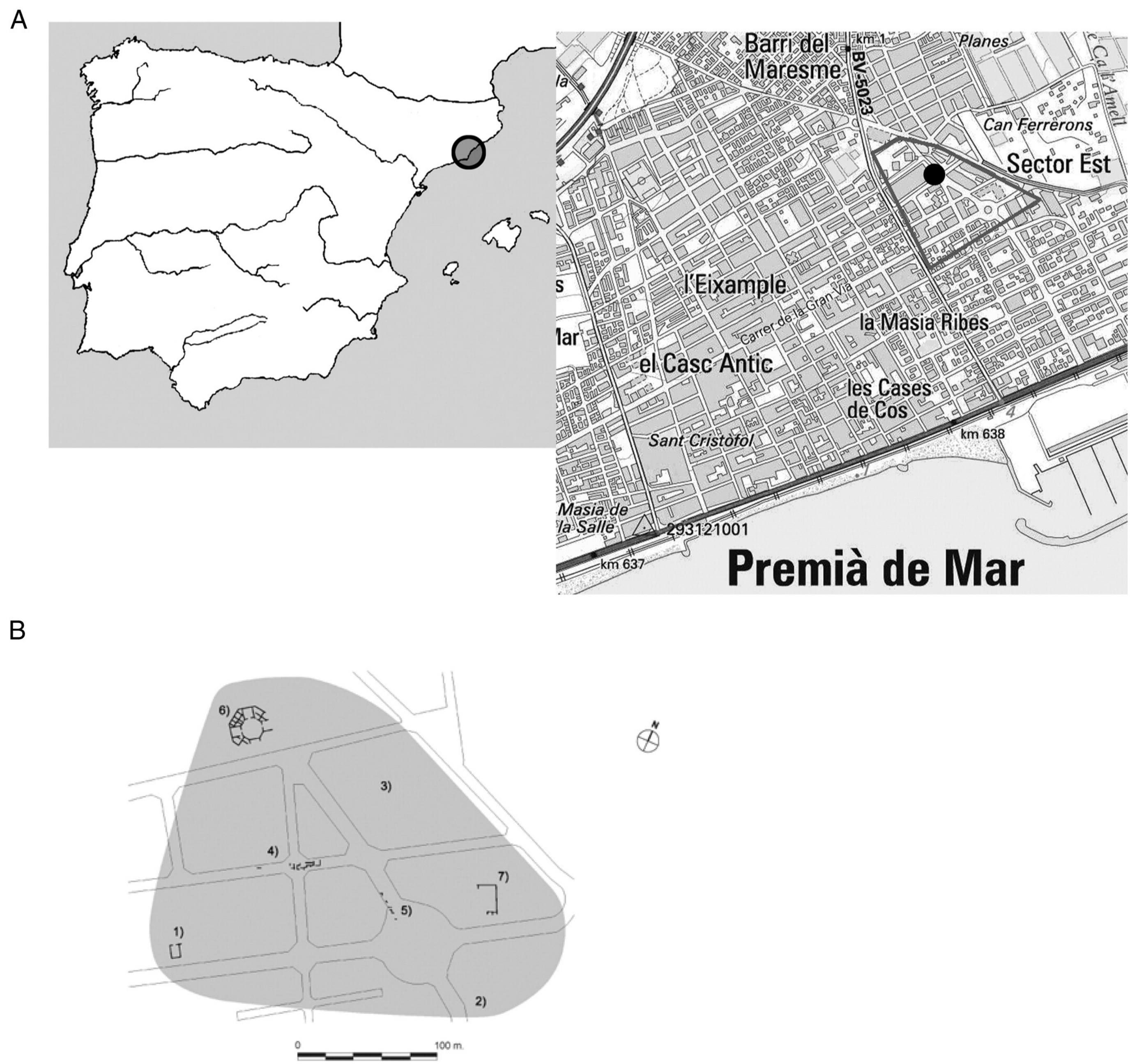

Fig. 1. A. Location of the site Gran Via- Can Ferrerons, in Spain and in Premià de Mar. B. The site Gran Via-Can Ferrerons with the seven points of findings: 1- Gran Via mosaic; 2- Mas Foixà; 3- Vallpremià; 4- Col·lector smelting ovens; 5- Santiago Rusiñol 5th century walls; 6- Can Ferrerons octagonal building; 7- Plaça Dr. Ferran pottery workshop.

Within this villa Can Ferrerons is a centralized building, the result of meticulous architectural planning (Fig. 2). It consists of two octagons, one embedded in the other. The central octagon was drawn inside a circle of 14.8 m in diameter or 50 Roman feet. The external octagon was drawn in a circle of 29.6 m or 100 Roman feet in diameter. Significantly, the radial walls that compartmentalize the space between the two circles are distributed evenly at 45°, confirmed by a measurement based on the circumference.

Four large rooms, of 6.6×6.35 m (42 m^2), open around the central octagon (Fig. 2: numbers 8, 9, 14 and 20). The other four sides between the large rooms, on the N, S, E and W, are connected with a subdivision of minor trapezoidal rooms following a symmetrical pattern. One of these latter spaces is occupied by the bath suite.

The resulting building is of singular complexity and clearly planned, emphasizing the geometrical over the functional. It is distinctly the result of a unique architectural design executed *ex novo* in a single construction phase.

2.2. Interpretative problems of the octagonal building and its dating

Octagonal plans are not very common in Roman residential architecture, although they occasionally appear in wealthy houses. Within Roman domestic architecture, the earliest octagonal building we know of is in Asinello (Viterbo, Italy) and it dates from the mid-1st century BCE (Barbieri, 1995; Broise and Jolivet, 2000; Marzano, 2007, 116–118, catalogue L375). It was a space for the production of oil, with an earlier use in wine production (Brun, 2004, 42). Also dated to the end of the 1st century BCE, the impressive maritime villa of Giànola, Formia, Italy, has an octagonal building (Ciccone, 1990; Marzano, 2007, catalogue L111), interpreted as a *nymphaeum*-

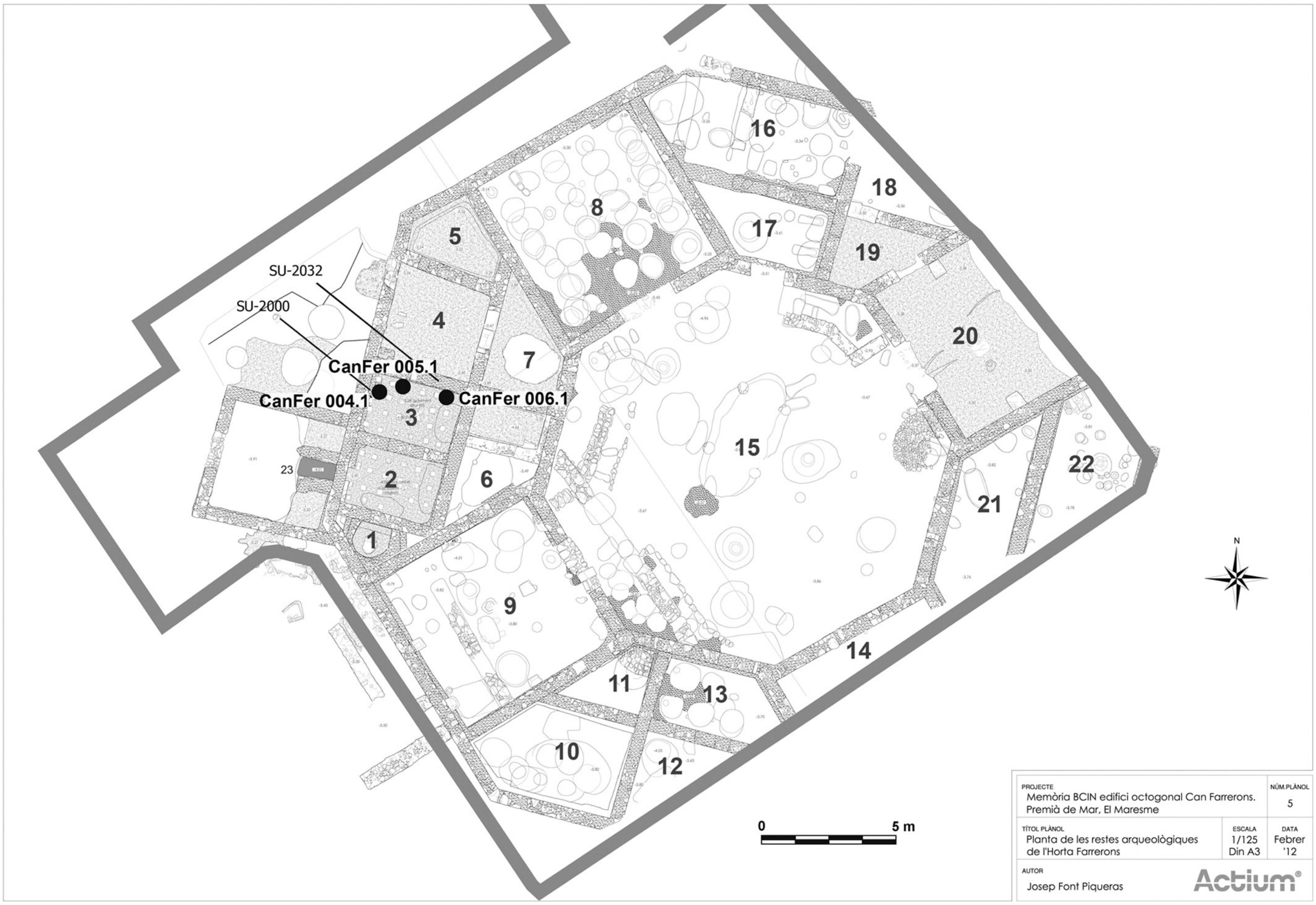

Fig. 2. Can Ferrerons' general plan with reference numbers of rooms. Sample CanFer 004.1 was taken from stratigraphic unit (SU) 2000; samples CanFer 005.1 and CanFer 006.1 were taken from stratigraphic unit 2032.

musaeum (*Nymphaeum*: Greek or Roman monument dedicated to the *nymphs*, caves and springs; *Musaeum*: monument dedicated to the *Musae*, the nine goddess daughters of Mnemosyne and Zeus in mythology). Ciccone (1995) suggests that it could have been an important influence in the construction of Nero's Golden House's octagonal hall, the most spectacular example of octagonal centralized building in early Empire residential architecture.

Octagonal halls occur frequently in palatial and wealthy domestic buildings of late Roman times, where the core room may be a regular polygon, such as an octagon, decagon, hexagon or a pentagon (Scagliarini Corlaita, 1995). Centralized buildings are very characteristic of Eastern architecture. The influence of oriental architecture comes through the great palaces of the emperors established in the east of the Empire. This led us to search in these residences for the understanding of the octagonal pavilion in Can Ferrerons.

We have studied a series of late Roman dining suites with an octagonal core room or even a regular polygon or a circular core with a conception similar to Can Ferrerons. One of the most interesting examples for comparison is the dining suite at the Diocletian palace of Split (Wulf-Rheidt, 2007) called *triclinium triumphale* by Radoslav (Bužančić, 2009). It consists of a central octagonal room that opens onto four rectangular rooms, one of them being the entrance. A centralized building appears again in the grand dining hall at the Galerius palace *Felix Romuliana*, at Gamzigrad (Serbia), dated between CE 298 and 311 (Vasić, 2007; Büllow, 2011). The decagonal hall called Temple of *Minerva Medica* in Rome (Guidobaldi, 1998, 2004; Biasci, 2003; Barbera et al., 2007; Magnani Cianetti, 2013; Barbera, 2013) has been recently interpreted as the main official banquet hall in the palace of Constantine in Rome. The Gülhane building in Istambul has a similar distribution; the centre of the great Imperial Palace in Constantinople was under Justinian known as the *Chrysotriklinios*' Octagon, perhaps to be identified with the Constantine's octagonal room (König et al., 2003; Kostenec, 2004).

In late Roman times private domestic architecture of the rich emulated that of public buildings, which are increasingly identified with palatial buildings. Therefore, centralized buildings became a form of self-representation for the upper classes. Consequently, we find banquet halls like the central hexagonal room in Antiochus' palace in Istanbul dated from the early 5th century (c. 430) (Naumann, 1965), repeating the main features of the Temple of *Minerva Medica* in Rome. The most striking parallel to the architectural layout of Can Ferrerons is the poliapsedated hall at the *Domus* over the *Sette Sale* in Rome (Cozza, 1976; Guidobaldi, 1986; Volpe, 2000): a hexagonal hall with its four sides opening onto four rectangular rooms, each one ended by a semi-circular apse. The other two sides open to rectangular rooms serving as entrances.

In the Iberian Peninsula there are also some centralized buildings with regular polygonal cores we must mention. The Roman villa of Rabaçal at Penela, Portugal (Pessoa, 1991, 2010; Pessoa and Madeira, 1995; Pessoa and Steinert Santos, 2001), built in the second half of the 4th century, is a centralized building with an octagonal peristyle core opening into the large reception rooms. Again, by the 4th century, in the Mexilhoeira Grande villa at Abicada, Portimao, Portugal (Viana et al., 1953; Duran Kremer, 2008, 2012), the reception suite has a central hexagonal peristyle core each side opening onto a rectangular space including the entrance. Valdetorres de Jarama Roman site (Arce, 1993;

Arce et al., 1997), from the second half of the 4th century, is also a centralized building with an octagonal peristyle at its core. Four of its sides open onto four rectangular main rooms.

All of these three examples present a fundamental difference to Can Ferrerons: their central spaces are peristyles (open courtyards), whereas Can Ferrerons has a central covered space that connects it directly with the surrounding rooms thus forming a single space for a unique use. Therefore the closest parallel to Can Ferrerons is to be found in the hexagonal hall at the *Domus* over the *Sette Salle* from the 4th century. If the parallel suggested is correct it indicates a reception room such as a dining room.

As has been discussed, the Can Ferrerons building fits well into the frame of late Roman domestic architecture. In spite of this there are octagonal domestic buildings built during other stages of the Roman period. This is the reason why absolute dating is of paramount importance, as it may completely change our interpretation.

2.3. Detailed description of the sampled walls and their archaeological chronology

As we cannot accurately date the building based on Roman architectural typology, it was of prime importance to find an alternative method to determine an absolute age of the building. The archaeological works have not been able to date its construction; consequently we decided radiocarbon dating of lime mortars would be an appropriate solution. It was commissioned from the team at the Åbo Akademi University (Finland) and the Aarhus University AMS ^{14}C Dating Centre (Denmark), who collaborate on developing mortar dating routines.

The three samples processed were taken from the *tepidarium* (heated room in a Roman bath suite) (Fig. 3) (room 3 in Fig. 2). Sample CanFer 004.1 was taken from stratigraphic unit 2000 and samples CanFer 005.1 and CanFer 006.1 (Fig. 4) were taken from stratigraphic unit 2032. The bath suite of Can Ferrerons is part of the original octagonal building. As stated above, it is a unique architectural design executed *ex novo* in a single construction phase. The walls were constructed in masonry work, from timber formwork of which different traces from the successive timber rows are visible in the mortar. The samples were taken from the first row in the deepest part of the visible walls in the *hypocaust* (Roman heating system) of the bath. Stratigraphic unit 2000 is part of the external octagon wall, and it closes the *tepidarium* on its western side (Fig. 2). Stratigraphic unit 2032 is the northern wall of the *tepidarium* (Figs. 2 and 3). Both walls were constructed in the same building phase.

The J. Font (2013) archaeological excavations report states that some excavated stratigraphic units have been dated to the first half of the 5th century. They correspond to demolition contexts and represent the dismantling of the original features in several rooms. The lower layer filling

Fig. 3. Room 3: the *tepidarium*. Samples CanFer 005.1 and CanFer 006.1 were taken from stratigraphic unit 2032 (the left wall with the door connecting with room 4: see Fig. 2) in the deepest part in the hypocaust.

Fig. 4. Sample CanFer 006 was taken from stratigraphic unit 2032. Notice the stones in almost herringbone arrangement, a 4th, 5th and 6th century technique.

the *hypocaustum* in room 3 (SU 1049) was of demolition and backfill with hundreds of *tegulae* (Roman roof tiles) and brick fragments, dozens of pipes, abundant iron nails, wall painting remains, as well as pottery. The date of the layer has been inferred from two whole DSP (*dérivée de sigillée paléochrétienne*: pottery produced in South Gaul dated from CE 370–700) ceramic vessels form Rigoir 18 (dated between CE 370 and 500) and Rigoir 23 (dated between CE 400 and 500). It is clearly of a 5th century context indicating the heating system's time of destruction. Therefore the construction must predate this: earlier in the same century (5th) or before.

3. Materials and methods

3.1. Sample description

The samples were inspected visually and with a stereo microscope. Special emphasis was given to finding detrital carbonate and dateable charcoal pieces. Cathodoluminescence (CL) was conducted on the sample powders that were hydrolysed with a CITL 4 cold cathode device (Cambridge Image Technology Ltd). The aim was to identify natural carbonates that had grown in equilibrium with sea-water and having a well-organized crystal lattice and a bright luminescence colour (e.g. Marshall, 1988; Pagel et al., 2000). No thin sections for petrographic microscopy were prepared because the samples were soft and they did not seem to contain limestone. All three samples are beige coloured and relatively soft and porous mortars. They are well preserved; only sample CanFer 004 has signs of slight surface weathering. The aggregate is fine-grained, mostly silt-sand and it is composed of rounded grains of quartz, feldspar and plagioclase. Most likely its origin is Quarternary, fluvial sandy deposits on the Pre-Variscan to Variscan, mostly igneous basement (Santanach et al., 2011). The binder of the mortar samples is homogenous, with very little lime lumps. The few small lumps that can be found are also beige coloured and only slightly lighter in colour than the binder matrix. These kind of coloured lumps may be underburned limestone residues and carry dead carbon (e.g. Pesce et al., 2009), but their CO_2 reaction rate is usually low during hydrolysis (Lindroos et al., 2014).The carbon yield of the 46–75 μm grain-size fraction was low: 2.83–3.94% (Table 1). This corresponds to 23.6–32.8% $CaCO_3$ and it reflects the abundance of the inert, fine-grained siliceous

Table 1
Hydrolysis data, ^{14}C ages and stable isotope measurements for the Can Ferrerons samples. $\delta^{18}O$ values are comparable with each other but not with values from standard measurement procedures (Craig, 1953). n.m = not measured.

SAMPLE	Weight	Reaction time	CO_2 fraction	^{14}C age	±	Calibrated age	$\delta^{13}C$	$\delta^{18}O$	Laboratory nr
Carbon yield	46–75 μm	t_0 − capture	Size	BP	Years	2σ confidence	VPDP	VPDP	
(%)	(mg)	(s)	(%)	(a)	(a)	(a; %)	(‰)	(‰)	
CanFer 004.1	179	4	0–24	1637	25	343–434 (80.1)	−31.48	−4.85	AAR-20032.1
3.94		24	24–47	1692	25	460–467 (1.0)	−21.67	−3.55	AAR-20032.2
		77	47–65	2028	25	488–533 (14.3)	−19.59	−3.39	AAR-20032.3
		530	65–92	not dated			n.m	n.m	
		1780	92–100	not dated			n.m	n.m	
CanFer 005.1	208	5	0–16	1585	25	415–540 (95.4)	−36.95	−8.44	AAR-20033.1
3.86		50	16–60	1699	25		−22.76	−5.45	AAR-20033.2
		260	60–92	1943	27		−20.82	−5.68	AAR-20033.3
		1765	92–97	not dated			n.m	n.m	
		2870	97–100	not dated			n.m	n.m	
CanFer 006.1	190	4	0–12	1582	35	401–554 (95.4)	−22.00	n.m	AAR-20034.1
2.83		23	12–52	1668	25		−21.87	−5.95	AAR-20034.2
		92	52–81	2071	29		−17.79	−4.93	AAR-20034.3
		630	81–97	not dated			n.m	n.m	
		1890	97–100	not dated			n.m	n.m	
85% H_3PO_4									

aggregate. The carbonate dissolved very rapidly: more than 50% dissolved during the first minute of hydrolysis (Table 1). The origin of the limestone used for lime production is unknown. The largest pieces of the three samples are shown in Fig. 5.

3.2. AMS ^{14}C dating

Mortar dating is a method where carbon in the inorganic calcium carbonate binder of the mortar is subjected to radiocarbon dating. The carbonate mineral calcite formed when the mortar hardened and thus the method dates the actual building event. The hardening reaction is:

$$Ca(OH)_2 + [^{14}C]CO_2 \rightarrow [^{14}C]CaCO3 + H_2O$$

(portlandite + carbon dioxide including ^{14}C → calcite + water)

The carbon dioxide carrying ^{14}C originates from the atmosphere and thus the mortar samples the contemporary atmosphere, which is the ideal situation for ^{14}C dating. The concept of mortar dating goes back to the 1960s (Labeyrie and Delibrias, 1964). They started with thermal decomposition of the carbonate to liberate CO_2. This approach was soon abandoned and replaced by diluted hydrochloric acid hydrolysis (e.g. Stuiver and Smith, 1965; Baxter and Walton, 1970; Folk and Valastro, 1976). From the beginning it was understood that there were other carbon sources than the binder calcite which contributed to the stable isotope signature and the apparent ^{14}C age. The main problem in mortar dating is contamination with dead carbon from either poorly burned limestone residues or from carbonate minerals in the aggregate. These will contribute with dead carbon of geological origin and increase the measured ^{14}C age (e.g. Stuiver and Smith, 1965; Baxter and Walton, 1970). Volk and Valastro (1976) developed a sample preparation protocol were they crushed and sieved the sample and collected several successive CO_2 fractions from a given grain-size window during the ongoing hydrolysis. The hydrolysis was controlled by adding the HCl drop-wise into a slurry of the mortar powder and water under vacuum until enough CO_2 for each ^{14}C measurement had been collected. They argued that the contamination is suppressed if CO_2 is collected from the very beginning of the hydrolysis reaction. Their studies were complemented with petrographic microscopy of the samples. The invention of AMS made it possible to separate small parts of the sample for dating (Tubbs and Kinder, 1990; Van Strydonck et al., 1992). This enabled further development of sequential dissolution because it was now possible to study narrow grain-size windows, small fractions of the carbon inventory or short intervals in the reaction progress. The Aarhus AMS Centre in Denmark developed a method based on procedures used for stable isotope (^{13}C, ^{18}O) measurements (Craig, 1953) and ^{14}C dating of geological and biological carbonates (e.g. Burr et al., 1992). 85% phosphoric acid (which is the standard, undiluted factory quality) in excess was poured from a side arm in the reaction vessel on the sample powder in vacuum and several CO_2 fractions were collected during the hydrolysis reaction. Usually 100–200 mg of a relatively narrow grain-size window, e.g. 46–75 μm was used (e.g. Heinemeier et al.,

Fig. 5. Pieces of the sampled material. From the left to the right: CanFer 004, −005 and −006.

1997). The procedure is described in more detail below. It is basically the same as Bookman et al. (2007) used for dating geological carbonate. This procedure effectively suppresses ^{14}C-dead carbon relative to binder carbon activity during the initial phases of the hydrolysis and it is possible to monitor dead carbon activity in later CO_2 fractions (Folk and Valastro, 1976; Lindroos et al., 2007). However, readily soluble recrystallizations will have an enhanced impact on the initial stages. The dating of a sample is therefore considered unsuccessful if the first CO_2 fraction yields significantly younger ages than the second CO_2 fraction, but the third fraction is more similar to the second one (for more details see Lichtenberger et al. (2015)).

Three samples taken from the *tepidarium* room were selected for testing the potential of mortar dating at Can Ferrerons. All 3 samples were taken so that they would represent the same chronology and even the same mortar batch. In this way the consistency of the results was checked. The samples were prepared according to the routine developed for the Aarhus AMS Dating Centre, but preparation was conducted on another preparation line at Åbo Akademi University, Finland. The line has some modifications: It is simpler and dedicated for carbonate hydrolysis only; its volume is smaller but it has a larger metallic cooler with a drainage screw enabling the use of diluted acids. The acid is let in through a burette instead of the side arm. The preparation routine can be shortly described as follows:

1) Some 50 g of sample was crushed with plastic covered pliers.
2) The crushed material was dry sieved in a sieve series with decreasing mesh size.
3) A 46–75 μm grain-size window was selected for washing with deionized water.
4) The 301–500 μm grain-size was tested for alkalinity with phenolphthalein.
5) Some 10 mg of the washed grain-size was spread over a glass and inspected with a microscope coupled to a cathodoluminescence (CL) device.
6) About 200 mg of the washed grain-size was put into a glass reactor in vacuum for hydrolysis with 85% phosphoric acid.
7) 300 ml phosphoric acid was let in onto the sample through a burette.
8) As the carbon dioxide (CO_2) effervescence started a first fraction of the gas was isolated for ^{14}C dating already after a few seconds (see Table 1). A consecutive second gas fraction was isolated within the first minute and a third within a few minutes. The isolated CO_2 fractions were kept isolated from each other in the preparation line until they were quantified (pressure measured) and cryogenically collected into glass vials. The three dated CO_2 fractions define ^{14}C profiles for each sample as the ^{14}C age is plotted against the dissolution progress parameter F ($F = 0 \rightarrow 1$; 1 denotes that all carbonates are dissolved after a few hours in this case). F can be expressed as follows:

$$F = 1 - M_t/M_0$$

Where M_t is the amount of dissolved carbonate at time t and M_0 is the amount of soluble carbonate before the hydrolysis starts. F is used instead of 0–100% because it relates to the dissolution constant Γ, which is considered later when dissolution rates are described.

$$\ln(1 - F) = -\Gamma t$$

More details on the sample preparation and AMS method can be found in e.g. Lindroos et al. (2007), Heinemeier et al. (2010) and Ringbom (2011).

The vials containing the CO_2 gas were sent to the Aarhus University AMS ^{14}C Dating Centre, where they were opened under vacuum and split into two aliquots. Part of the CO_2 gas was used for $\delta^{13}C$ and $\delta^{18}O$ analysis on a GV Instruments Isoprime stable isotope mass spectrometer to a precision of 0.15 ‰, while the rest of the gas was converted to graphite for AMS ^{14}C measurements. Due to damage to the Centre's own EN tandem accelerator, the resulting CO_2 was submitted for graphitization and AMS analysis to the Accelerator Mass Spectrometry Laboratory, Accium Biosciences (Seattle, WA, USA) under the direction of Ugo Zoppi (Zoppi et al., 2007). The results are reported according to international convention (Stuiver and Polach, 1977) as conventional ^{14}C dates in ^{14}C yr BP (before present = CE 1950) based on the measured $^{14}C/^{13}C$ ratio corrected for the natural isotopic fractionation by normalizing the result to the standard $\delta^{13}C$ value of −25‰ VPDB. The calibration of the ^{14}C ages to calendar years was done using the IntCal09 calibration curve and the OxCal 3 program (Bronk-Ramsey, 2001). All calibrated results are reported at 95.4% confidence level. Note that the $\delta^{18}O$ values were produced using 85% phosphoric acid and they are therefore not comparable with carbonate values obtained by routine methods (Craig, 1953). We use them for sample characterization within this project. Table 1 shows the results together with some of the laboratory parameters.

4. Results and discussion

The microscopic studies showed that the samples are rich in aggregate composed of fine-grained sand, mainly quartz with some feldspar. The carbonate binder content is low, which is reflected in the low carbon yields of the dated material; 2.83–3.94% (Table 1). The theoretical maximum yield is 12% for pure calcium carbonate. The low binder content is due to the fine-grained filler and partly due to weathering of the samples. Fig. 6A is a CL micrograph of the dated 46–75 μm grain-size fraction before hydrolysis and Fig 6B shows the remains of the same sample after hydrolysis. The fraction dated revealed only a few natural calcite grains from limestone or marble (Fig 6A). They are either from the aggregate sand or marble splinter. The bright orange colour indicates low magnesium content (Habermann et al., 2000). This means that they are not dolomites and they are soluble in the hydrolysis and therefore absent in the residue after hydrolysis (Fig. 6B). Consequently they will contribute with dead carbon in the dating. Less bright red

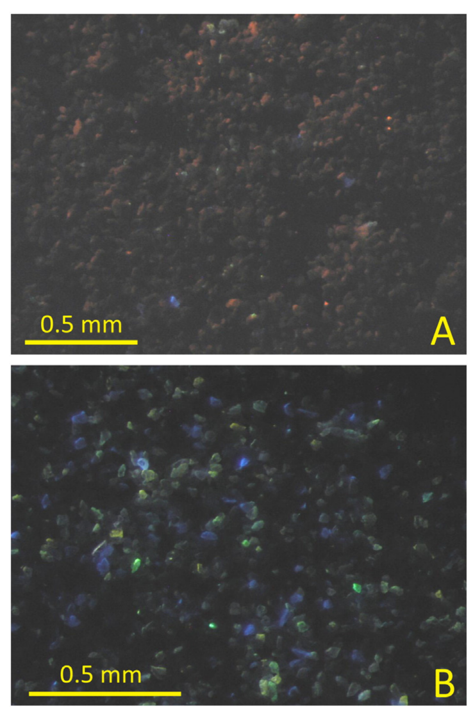

Fig. 6. A, CL micrograph of the 46–75 μm grain-size fraction that was sent for dating. Bright orange-red grains are natural calcites = contaminants. B, the residue of the same sample after hydrolysis. All red grains have dissolved. (For interpretation of the references to colour in this figure, the reader is referred to the web version of this article.)

grains represent the underburned limestone residues mentioned earlier. Blue and bright green grains are quartz. Dull green grains are feldspar or quartz. For applications of CL in mortar studies see e.g. Lindroos et al. (2007) and Szczepaniak et al. (2008).

Fig. 7 displays the ^{14}C ages as functions of the progressing dissolution of the sample in phosphoric acid. About half of the carbonate in each sample dissolves in less than one minute. This first half yields rather uniform ^{14}C ages displayed as flat graphs in the plot. Our interpretation is that the carbon source for about 50% of the available carbon is homogenous (the binder) and the contamination is insignificant. Alternatively there is a contaminant with the same dissolution constant as the binder. This is unlikely and it is even more unlikely that there would be significant amounts of it (for dissolution rates and ^{14}C profiles see Lindroos et al. (2007)). After this the third CO_2 fractions display increasing ^{14}C age indicating different degrees of dead carbon contamination in the samples. Probably it originates mainly from the underburned limestone residues because of the slow dissolution. Accordingly, sample CanFer 005 is least contaminated and most reliable. A combined calibration (OxCal 3/combine for the first CO_2 fractions of each sample; K^2 passed) of the ^{14}C ages for the initial CO_2 fractions gives the age CE 410–540 for the room. Omitting sample CanFer 004, which differs slightly from CanFer 005 and CanFer 006, has little effect on the calibration: It narrows the age span to CE 420–540 (Fig. 8).

An alternative interpretation is that the very negative $\delta^{13}C$ values for the first CO_2 fractions is a sign of degradation and *re*-crystallization (MacLeod et al., 1990; Lichtenberger et al., 2015) and that there is actually a younger contaminant offsetting the dating of the first fractions. Another hypothetical indication of this is that the first CO_2 fraction of sample CanFer 004, which is larger than the ones of CanFer 005 and −006, appears older. We therefore did a test and made the corresponding combined calibration for the second CO_2 fractions of all the samples (OxCal 3/combine; K^2 passed). The result would be 1686 ± 15 and a calibrated date at CE 263–411 at the 95.4% significance level (and CE 320–420; 89.1%) which is similar, and only slightly older considering that the second fractions are probably to some extent affected by dead carbon. However, the concept of re-crystallization is theoretical, not visible as stalactite crusts on the walls nor as efflorescent growths in the stereo microscope inspection. The very negative $\delta^{13}C$ values may also have formed as fractionation response to two rapid kinetic reactions: 1) rapid hardening at the surface at high pH values resulting in a negative signature for the whole sample (Zouridakis et al., 1987; Van Strydonck and Dupas, 1991), 2) rapid dissolution during hydrolysis resulting in very negative values for the initial CO_2. We prefer this latter interpretation mostly because of the flat profiles, but it is possible that there is some re-crystallization and that the wall is slightly older than CE 420–540.

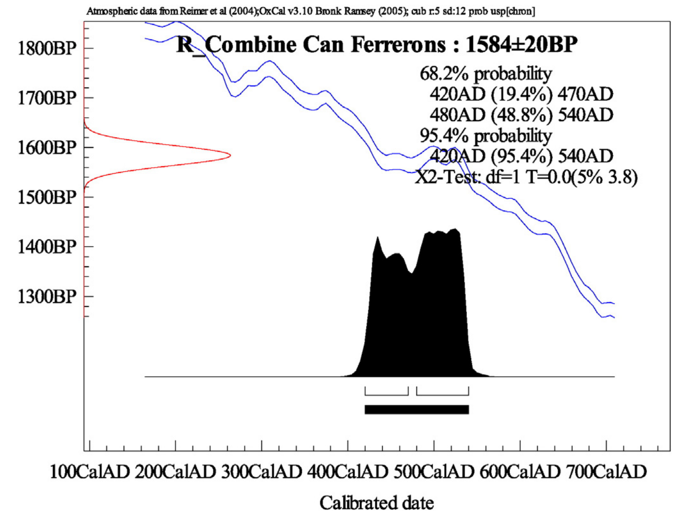

Fig 8. Combined calibration of the ^{14}C measurements of the initial CO_2 fractions of samples CanFer 005 and CanFer 006.

As discussed before AMS ^{14}C dating indicates that the age is between CE 420–540, at 95.4% confidence level. Significantly this date coincides with the known archaeological strata dates. In fact, the analysis of the building technique proved to be similar to other buildings in the region from the 4th, 5th and 6th centuries. Especially relevant is the use of the "*pseudo spicatum*" in Can Ferrerons, as we can see in Fig. 4. Masonry walls with stones in almost herringbone arrangement from the 5th century are to be found in the bishop's reception hall and in the bishop's residence in Barcelona (Beltrán de Heredia, 2009, 147); in the funerary building of Sant Cugat (Barcelona) (Artigues et al., 1997, 35); and from the end of the 4th century in the first phase of Sant Julià de Ramis *castellum* (Burch et al., 2006, 43). Further, as we have seen above, the most ancient archaeological contexts excavated in the octagonal building are from the 5th century in spite of containing some artefacts from earlier centuries. We have concluded that Can Ferrerons was built in the 5th century.

Dating the construction of the Can Ferrerons' pavilion to the 5th century fits with our most probable interpretation as late Roman domestic architecture. As we have seen above the centralized buildings with a core room either in the shape of an octagon, a decagon, a hexagon, or a pentagon in late Roman domestic housing are usually banquet suites. We have to bear in mind that *triclinia* (dining rooms) served as audience halls also. Some of them are simply regular polygonal halls with apses at the sides to fit the *stibadia* (D shaped dining couches), as at the so called Temple of *Minerva Medica* in Rome or Antioch's palace in Istanbul's

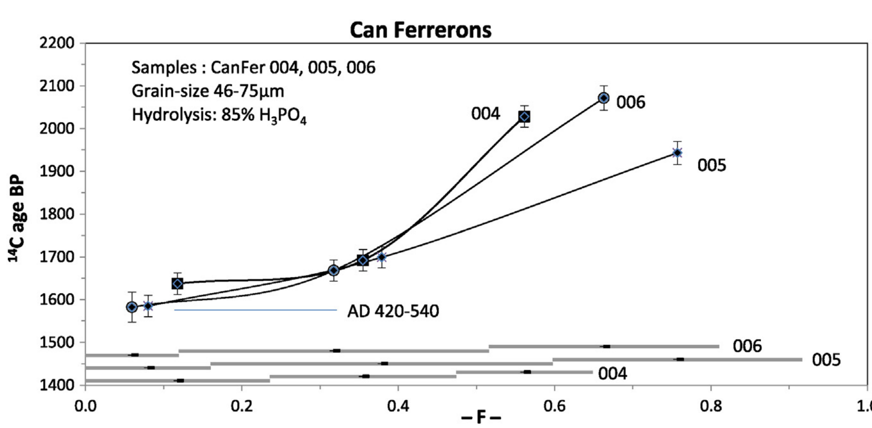

Fig 7. ^{14}C profiles of three similar samples. The ^{14}C values are plotted against the dissolution progress parameter F. ($F = 0 \rightarrow 1$). $F = 1$ means total (100%) dissolution. The grey bars along the abscissa denote the relative sizes of the CO_2 fractions (3 fractions/sample).

octagonal hall. Notwithstanding this, other regular polygonal halls open to rectangular greater rooms, like the *Domus* over the *Sette Sale* hexagonal hall that opens to four rectangular rooms with apses. It reminds us of Can Ferrerons architectural structures, although there is a chronological difference between them as Can Ferrerons is to be dated in the 5th century, a century later than the *Domus* over the *Sette Sale*.

5. Conclusions

Can Ferrerons near Barcelona is situated in a basement rock area and the risk of significant limestone aggregate contamination is small. Microscopic studies and CL revealed very little limestone as expected. The relatively dry Mediterranean climate is favourable for preservation of the mortars. The 3 samples yielded 3 similar ^{14}C profiles with a pattern usually found in well-dated samples. The increasing ages, which were produced after 50% dissolution are common in samples in general and they are attributed to slow dissolution of underburned limestone residues. The dating CE 420–540 is basically reliable, but it is possible that there is a minor re-crystallization effect making the dating appear slightly too young.

Radiocarbon dates coincide with archaeological strata dates and with the building technique date. The 5th century fits with the interpretation of the monument as late Roman domestic architecture. All these coincidences support each other giving the date a high degree of reliability. Now that we are certain of its age, the 5th century, we have a solid basis from which to extend our research.

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