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An application of luminiscence dating to building archaeology: The study of ceramic building materials in early medieval churches in north-western France and south-eastern England

Un caso de aplicación de datación por luminiscencia a la arqueología del edificio: el estudio de la cerámica constructiva en las iglesias altomedievales del Noroeste de Francia y el Sudeste de Inglaterra

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Abstract

The research reported in this thesis concerns the re-evaluation of an archaeological assumption surrounding the origin of Ceramic Building Materials (CBM) used from the 9th to the 11th century in religious buildings of north-western France and south-eastern England. Are the bricks used in the masonry structures Roman *spolia* or *a novo* productions?
Amongst the dating methods that can contribute to building archaeology, it is the technique of stimulated luminescence applied to CBM that is the focus of this study. Results from thermoluminescence (TL) and optically stimulated luminescence (OSL) dating performed on 52 CBM samples from 11 churches showed that the practice of reusing Roman brick was commonplace in small parish churches, but also that brick-making was not a totally unknown skill of the early medieval craftsmen as it has long been supposed. Most importantly, by identifying that the building material is contemporary to the church, a defined chronology emerges resulting in a new and extremely useful reference point in the history of early medieval architecture.

Keywords: Carolingian and Anglo-Saxon architecture, churches, ceramic building materials, *spolia*, luminescence dating, building archaeology.

Resumen

La investigación presentada en esta tesis se ocupa de la reevaluación de un supuesto arqueológico entorno al origen del material cerámico constructivo (CBM) empleado entre los siglos IX y XI en los edificios religiosos del Noroeste de Francia y el Sudeste de Inglaterra. ¿Son los ladrillos empleados en las estructuras de fábrica *spolia* romana o producciones *a novo*?
Entre los métodos de datación que pueden contribuir a la arqueología del edificio, la técnica de luminiscencia estimulada aplicada al CBM es el centro de este estudio. Los resultados de la termoluminiscencia (TL) y de la luminiscencia estimulada ópticamente (OSL), aplicadas en 52 muestras de CBM tomadas en 11 iglesias, evidencian que la práctica de reutilizar ladrillos romanos era común en pequeñas iglesias parroquiales, pero que también la técnica de elaboración de ladrillos no era totalmente desconocida para los artesanos altomedievales, como se había supuesto hasta ahora. Lo que es más importante, al identificar material constructivo contemporáneo a la iglesia, se obtiene una cronología concreta que se convierte en un punto de referencia nuevo y extremadamente útil para la historia de la arquitectura altomedieval.

Palabras Clave: arquitectura carolingia y anglosajona, iglesias, material cerámico constructivo, *spolia*, datación por luminiscencia, arqueología del edificio.

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1. INTRODUCTION

1.1. Early medieval buildings

Geographically, this study covers the regions of Normandy and Pays-de-Loire in north-west France and the counties of Kent and Essex in south-east England (Fig 1).

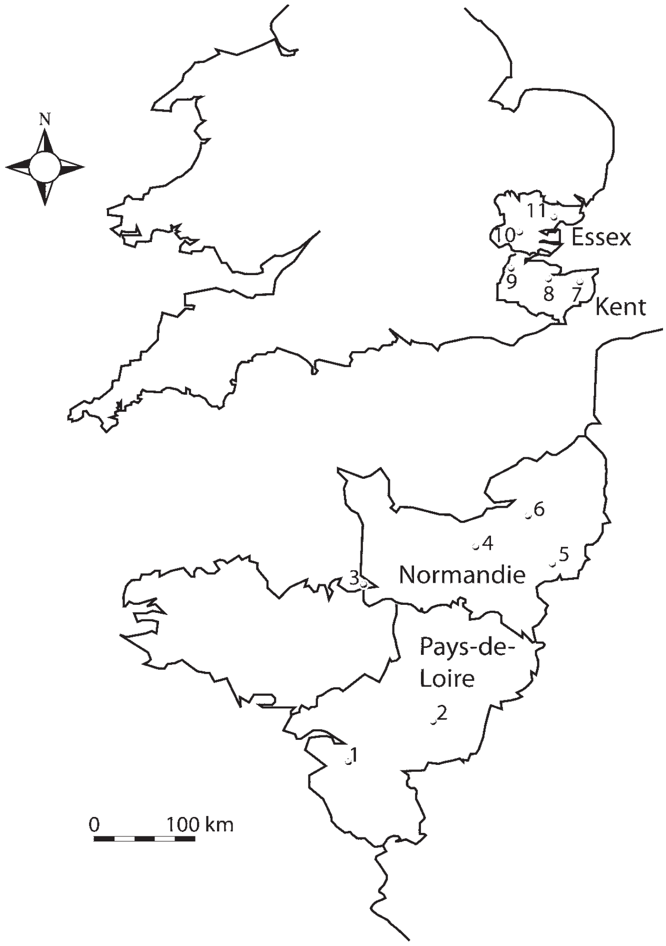

Fig. 1. Location of the sites: 1: Saint-Philbert-de-Grandlieu, 2: St Martin's Angers; 3: Notre-Dame-sous-Terre in the Mont-Saint-Michel; 4: Vieux-Pont-en-Auge; 5: Rugles; 6 : Condé-sur-Risle ; 7: St Martin's Canterbury ; 8 : Lower Halstow ; 9 : Darenth ; 10 : Chipping Ongar; 11: Holy Trinity's Colchester

In the French area, Carolingian architecture ranges from the second half of the 8th century and to the 9th-10th centuries for the most significant buildings, but extends into the 11th century for parish churches (Sapin, 2006, 77). In England, Anglo-Saxon architecture is generally divided into three periods: Early Anglo-Saxon (from the 6th to 8th century), Middle Anglo-Saxon (from the 9th to mid-10th century) and Late Anglo-Saxon (from the mid-10th to Norman Conquest) (Morris, 1983; Fernie, 1983). However, it can also be considered by the architecture of Norman churches built after 1066 by native Saxon builders using the traditional Anglo-Saxon building methods: this period is qualified as the Saxo-Norman overlap.

Carolingian/pre-Romanesque and Anglo-Saxon architecture are both inherited from Roman and eventually, Byzantine traditions (Barral i Alet, 1987). The plans for the most prestigious buildings usually emulate the basilical plan (Heitz, 1987, 171). For the more modest churches, the plan is more basic: a simple square nave with a square or apsidal chancel (Kerr & Kerr, 1983, 11-12). In both countries, the fabric is usually made of *petit appareil* (especially in France) or small irregular rubble usually covered by a plaster to hide the rough aspect of the wall (Hubert, 1938, 91; Sapin, 2006, 82; Kerr & Kerr, 1983, 31). CBM are also used in the masonry (Baylé, 1997, 445; Sapin, 2006, 82) as voussoirs in head openings, in horizontal rows (more frequently in French architecture), in herring-bone pattern or jambs or quoins (more common in Anglo-Saxon architecture). This mixture of stone and CBM is also a Roman inheritance.

1.2. The use of CBM in early medieval architecture: Hypothesis of re-use

The Romans first become experts in the know-how required for the transformation of clay into ceramic (Perlich, 2008, 9) and their Empire develops into the conduit for the diffusion of the production and use of the material (Lynch, 1994, 3). Legions arriving in Gaul in BC 58 and in Britain in AD 54, install brick/tile-making workshops where they settle and the new technology is adopted in the conquered territories. With the fall of the Empire and the withdrawal of the Roman legions, brickmaking appears to fall into disuse (Morant, 1768, 298; de Bouärd, 1975, 55-6). The use of the material, however, continues to appear in built structures, the early medieval builders supposing to salvage materials from Roman ruins. Whilst in north west Europe brickmaking seems to cease, on the rest of the continent Roman know-how of tilemaking is preserved and developed such as in Flanders (Coomans & Van Royen, 2007, 1 ; Perlich, 2008, 12-3). The Cistercian order that spread over Europe in the 12th century, is supposed to promulgate the technique, a role taken and developed afterwards by the Hanseatic League in the 13th century (Moore, 1991). From then on, brickmaking and its use in architecture intensify (Morriss, 2000).

The hypothesis of Roman CBM re-use in early medieval buildings was proposed in the 18th century in England (Morant, 1768, 298). However, in the 1960's, Davey and Jope, being cautious towards this too general an assumption, considered that further examination should be undertaken on the material in the buildings (Davey, 1961; Jope, 1964, 113). Such doubts are similarly raised by the discoveries in England of decorative floor tiles in Westminster, York, Peterborough, Coventry, St Albans, and Canterbury, all from 10th-12th century archaeological contexts (Betts, 1996; Betts *et al.,* 1991, 37). For the Carolingian Empire, there exists indirect evidence of brick production in the early Middle Ages when Einhard, friend, counsellor and biographer of Charlemagne, orders in a letter the making of 260 large bricks (Greenhalgh, 1989; Norton, 1983, 36). Another testimony is provided by Dudo of St Quentin, biographer of the Dukes of Normandy, who mentions the building site of the sanctuary of la Trinité, at Fécamp (granted by Richard I), the techniques used on the site and particularly the manufacture of CBM (Lair, 1865, 290-291; Renoux, 1991, 473-5). However, there is no evidence of what kind of material is made (wall bricks or roof tiles). In the 1950's, concerning the Collegiate church of St Martin, American archaeologist Forsyth suggests the existence of Carolingian bricks used in the masonry (Forsyth, 1953, 25). Between 1969 and 1972, on the 9th-10th century site of la Médecinerie at Saran (Loiret) a dozen ovens are discovered, revealing a production site of CBM especially for antefixa and modillions (Debal, 1969; Chapelot, 1970). Despite all the evidence, archaeologist de Bouärd declares that on the basis of the limited amount of CBM used in early medieval buildings in northern France, these materials are likely to have been salvaged from abandoned Roman sites (1975, 55-6).

One of the aims of this work is therefore to evaluate whether bricks used in the building of Anglo-Saxon or pre-Romanesque churches are Roman *spolia* or materials contemporary to the early medieval construction.

2. METHODOLOGY

To answer the archaeological question related to the origin of CBM used in early medieval architecture, the dating of CBM has been undertaken by the method of luminescence. The study will elucidate whether they are reused Roman materials or medieval products. In the case of medieval production, and if brickmaking is assumed to be contemporary with the construction, then dating the brick can be approximately assimilated to dating the masonry. Then not only the original building date can be determined or checked, but also by carefully choosing the brick from the masonry to be sampled and analysed, its phasing can be defined. We describe here the methodology followed to optimise the selection of the materials bearing the «age» information within the CBM.

2.1. Sampling procedure

The brick sampling strategy was designed in conjunction with an assessment of the historical and archaeological questions to be answered. Where possible, multiple samples were taken per building phase to check their individual contemporaneity and to achieve a more precise date of the phase, in reducing the uncertainties on the mean.

The bricks were sampled either with a hammer and a burin, or with a core drill designed for dry or wet cutting.

Despite the quantity of material luminescence requires, aesthetic damage is minimized by reducing the size of the samples (using a small diameter core drill bit) and by repairing the hole with pigmented mortar as close to the original brick colour as possible. The samples were then analysed in the laboratory.

The brick sample was prepared for analysis in the laboratory by sawing a section of the material for characterization of the fabric. Another portion of the brick was cut, gently crushed and sieved according to the grain sizes required and etched to remove unwanted minerals.

2.2. Phenomenon of luminescence: definition and description

The luminescence phenomenon is based on the property of irradiated crystals to emit light during stimulation by heat or light. This light emission results from the cumulative effects of natural irradiation on crystals within the ceramic material. The irradiation by α and β particles and the γ and cosmic rays causes ionisation within the crystal. The α, β particles and γ rays are emitted during the disintegration of radioelements such as uranium, thorium and potassium that are dispersed in the ceramic fabric and in the environment. During the ionisation process, electrons are liberated from their parent atoms in the crystal and are trapped at crystal defects. The number of trapped electrons increases with radiation dose. Heat or light can provide sufficient energy to liberate the trapped electrons, which recombine with holes at luminescent centres, resulting in the emission of photons: this phenomenon is thermoluminescence (TL) or optically stimulated luminescence (OSL) (Aitken, 1985).

2.3. Principle of the method

The last archaeological firing of the ceramic empties the traps, and thereafter the traps can again acquire electrons freed by the natural irradiation. The quantity of cumulative dose is called the paleodose and is proportional to the time elapsed since this process and to the dose rate. In its simple form, the age equation of the method is therefore: $t=Q/I$ where t is the age of the brick or the time elapsed since the last firing to analysis in the laboratory (expressed in years); Q is the paleodose (in Gray = Gy) an I is the annual dose rate (Gy/yr) (Aitken, 1985).

2.4. Determination of the paleodose

The paleodose is determined from grains extracted from the ceramic. Different techniques for measuring the paleodose are available depending on the nature and the size of the grain selected. The polymineral fine grain technique, used in the Bordeaux laboratory, employs grains in the range 3-12 µm and includes quartz, feldspars and other alumino-silicates. The coarse grain technique uses coarse quartz grains (90-150 µm for Durham and 80-200 µm for Bordeaux). To determine the paleodose, the measured luminescence signal related to the unknown archaeological dose (called «natural signal») is compared with the measured luminescence signals related to a known laboratory dose applied using a calibrated β-source («regenerated signals»). Both laboratories used an additive dose and regeneration procedure: on multiple aliquots (TL) in Bordeaux, and on single aliquot (OSL) in Durham. In Bordeaux, where the polymineral fine grain technique was used, further analysis was required to take into consideration a phenomenon of signal loss, called «anomalous fading», associated with feldspar minerals. It consists of measuring the evolution of the luminescence signal through time following laboratory irradiation (Blain et al., 2010).

2.5. Determination of the annual dose rate

The different contributions to the annual dose rate arise from sources of radiation within the grains, the ceramic, the environment (the rest of the masonry, the ground) and also from cosmic radiation. To determine the contribution from sources within the grains, ICP-MS analysis was carried out in Durham with grains used for paleodose determination and recovered following luminescence measurements. The average U, Th and K concentrations within the grains were used to calculate the internal grain dose rate. The sample contribution concerns β and α dose rates, the latter contribution being removed in Durham by etching with HF which enables the removal of the outer surface layer (20 µm) of the grains corresponding to the á penetration depth. These contributions are determined from K, U and Th concentration measurements from homogenised powdered brick or bulk sample by high resolution γ-spectrometry. These concentrations are then converted into the related dose rate using the conversion factors determined by Adamiec and Aitken (1998). In Durham, β-TLD is used with powdered material to directly evaluate the b dose-rate. In both laboratories, high resolution γ-spectrometry provides an indication of the state of disequilibrium within the uranium-series. A secondary indication of the radon emanation is provided by thick-source alpha-counting (Durham). Finally, the γ and cosmic contribution from the environment of the sample was evaluated using *in situ* dosimetry where phosphors were left for several months in or nearby the sampled location and analysed in the laboratory to measure the average dose rate during the measurement period (Blain *et al.,* 2010).

If the bricks appear to be reused and hence sampled in a secondary context, the dose rate needs to be adjusted to take account of the differences between the nature and composition of the environment in these two contexts, which we assume to be in different locations, location 1, before the reuse and location 2, as sampled.

The adjusted total annual dose rate related to the two-phase model corresponds to the weighted sum of the dose rate measured at location 2 (sampled) and the dose rate at location 1 (i.e. before the reuse). Since the beta dose rate is derived from sources within the brick, it is only the gamma and cosmic components of the dose rate that may have changed between the two phases of use if we assume the moisture conditions are similar.

Since the details of location 1 are not known, the combined gamma and cosmic dose rate during the period of primary use must be estimated. This estimate is based on the assumption that the brick was located in a brick wall of composition similar to the sampled brick and where the cosmic dose rate is typical. An uncertainty of ±25% is assigned to this estimate.

The adjusted total dose rate is obtained by multiplying the combined gamma and cosmic dose rate for each location by the respective durations in each location, expressed as a fraction of the brick age (i.e., time elapsed since manufacture).

3. STUDY CASES IN FRANCE

The work first deals with the study of a group of buildings in north-western France, which display analogous building methods and techniques, such as the use of brick as voussoirs and/or laid in horizontal rows in the masonry, similar to the style of Roman or Byzantine architecture. The question regarding the origin of the brick can be problematic: are they Roman reused material as suggested by de Boüard in 1975 or medieval products? Bricks are moreover an important component since they can help date the monument if their manufacture is contemporary with the construction. Amongst this group of buildings, some provide architectural markers for dating since they represent key-sites in the history of architecture, acting as references for other buildings displaying similar architectural features. However not all such buildings may be contemporary, and the situation is usually more complex. The dates for this group have been debated, fluctuating between the Carolingian period and the early 11th century. The dating of these key-sites is therefore essential in order to establish the extent of the influence within the group between the different regions. To provide an answer to these questioning, a number of religious buildings in Pays de Loire and Normandy were selected on the basis of the use of the CBM. The choice was focused on buildings where the organized and structuralised mode of use of CBM revealed a purposeful selection of these particular materials, situations where the bricks were more likely made for the building and are therefore contemporary to it. This work first concerns the abbey church of Saint-Philbert-de-Grandlieu which constitutes the inferior chronological earlier limit of this study, the Carolingian being well accepted for the origin of the building. The second building is the Collegiate church of Saint-Martin in Angers, sampled before a large restoration program prevented the access of the original preserved standing features of the building. The third building, the underground church of Notre-Dame-sous-Terre, was chosen since it constitutes the oldest standing witness of the monastic origins of the Mont-Saint-Michel. The remaining buildings in Normandy included the parish rural churches of Vieux-Pont-en-Auge, Rugles and Condé-sur-Risle.

3.1. Saint-Philbert de Grandlieu

Records indicate that between 814 and 819 a monastic church was built on the top of a schist mount and beside the River Boulogne, in Saint-Philbert-de-Grandlieu (Chifflet, 1664). To protect themselves from the Norse incursions, the monks of Noirmoutier took refuge in St-Philbert-de-Grandlieu in 836 (Chifflet, 1664 ; Poupardin, 1895), but 11 years later, the raiders ransacked and burnt the church (Chifflet, 1664). When the Norse reiterated their assault in 858, the monks abandoned the church (Lasteyrie, 1912). In the late 10th or early 11th century, they came back to St-Philbert. The minster became a priory and reparation building works were undertaken (Leboutteux, 1965). Few records have survived for the period

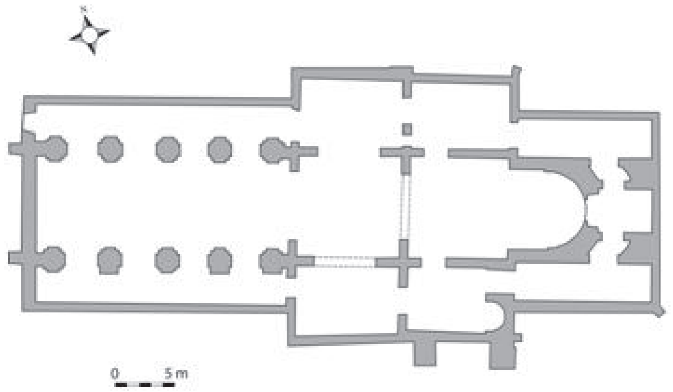

Fig. 2. Plan of the abbey church of St Philbert de Grandlieu, in its current state (after CEM, in Hebber-Suffrin *et al*., 1997)

between the 12th and the 16th century. Although left relatively untouched during the French Revolution, the church underwent minor repairs in the 19th century (Lebouteux, 1965). After a first series of archaeological excavations in the last decade of the 19th century (Maître, 1898) and a restoration program, the church finally became a listed building on 15th April 1896. Despite all the mutilations, the church of Saint-Philbert is the most authentic surviving witness of religious Carolingian architecture in France today (Maître, 1899).

The current church consists of a long aisled nave separated from the chancel by a salient transept. The study focuses on the transept crossing and its junction with the north-east chapel (Fig 2). The building walls are mainly made of local rubble (Lebouteux, 1965) but tuff is also used in alternation with bricks in the arches and the jambs of the openings (Lebouteux, 1965).

The meticulous archaeological analysis of Lebouteux in the 1960's highlighted the eastern wall of the north transept arm as ancient on the basis of the bricks in the openings (excluding the small door where the stone-brick alternation is not regular and its imposts have been typologically dated to the 11th-12th century). The south wall between the north chapel and the chancel also displays a particular feature. There is a remaining jamb made of bricks and stones that seems to be original (Lebouteux, 1965).

Before restoration work by the Monuments Historiques commenced, a program aiming to revise the earlier archaeological studies, led by Heber-Suffrin, Prigent and Sapin was implemented from 1997 to 2000. The archaeological interpretation from this recent study showed the current state of the transept is not original but has evolved with later restorations. The eastern wall of the north arm would be prior to this rebuilding, but the little door between the transept and the chapel might be a later insertion, as suspected by Lebouteux (1965).

The focus of this study concerns the use of CBM in the building. The first question concerns its origin: reused Roman materials or early medieval production? An antique origin is viable on the basis of the presence of other Roman materials such as the column elements discovered by Maitre on site. However, there is no archaeological evidence of ancient classical occupation of the site. The Roman town at Rezé (5 km from Saint-Philbert-de-Grandlieu) could, however, explain the presence of the ancient materials. The transport by river of materials over such a distance would have presented no obstacle to the builders of Saint-Philbert as is revealed by the presence of materials from Anjou (100 km far from Saint-Philbert) found among the building materials of the church. However, the CBM used in the arches are very homogeneous in size, colours and fabric, suggesting a contemporary production of these materials for the purpose of the building.

The second part of the study concerns the debate related to the eastern sections of the building and particularly the transept. Does it belong to the primitive building as suspected by de la Croix or to a later building phase as suggested by Maître and the recent studies? Moreover, the aim is to evaluate the phasing chronology between the crossing, the north arm and the north chapel of the chancel.

Four bricks were sampled from the south and eastern arches of the crossing. Four further brick samples were taken from two other locations in the same arches, two more from the jamb of the junction wall between the chancel and its north chapel and finally, two last samples were taken from the doorway between the north transept and the chapel. These last eight samples were only analysed in Bordeaux following the TL method applied on polymineral fine grains.

Following the fine grain technique, the age results, after correction of the fading, range from 1020±80 years to 1360±80 years (Table 1). Using the coarse grain technique, the age results vary from 931±84 to 1679±153 years (Table 1). The disparity in the results (Fig 3) shows that the limits of the method must be considered with caution and that further fundamental investigation is necessary. Uncertainties allocated to the dates relating to the fading correction on the polymineral fine grains data and the presence of internal radioactive inclusions in the coarse grains, means that the definition of the phasing is not possible at this time. However, the preliminary results show the builders of St Philbert mainly used early medieval bricks (manufac-

Location	Sample	technique	Q (Gy)	I (mGy/yr)	Age (years) in 2006	Dates (AD) ±1 tot
South arch of the crossing	Bdx10219	Fg	7.92±0.41	6.21±0.26	1280±90 (69)	726±90
		CG	7.69±0.58	4.71±0.18	1601±137 (123)	405±137
	Bdx10220	Fg	6.90±0.39	6.75±0.28	1020±80 (67)	986±80
		CG	5.85±0.57	5.02±0.22	1165±121 (113)	841±121
	Bdx10221	CG	3.52±0.56	4.29±0.19	822±134 (130)	1184±134
	Bdx10222	CG	4.61±0.34	4.21±0.32	1056±115 (107)	910±115
Door transept, north chapel	Bdx10223	CG	8.49±0.70	5.06±0.22	1679±153 (139)	327±153
	Bdx10224	CG	4.55±0.39	5.15±0.22	931±84 (76)	1075±84
Esat arch of the crossing	Bdx10225	CG	6.53±0.57	4.16±0.16	1629±149 (135)	377±149
	Bdx10226	Fg	9.27±0.53	6.82±0.28	1360±80 (76)	646±80
		CG	6.32±0.58	5.00±0.19	1265±125 (116)	741±125
	Bdx10227	CG	5.41±0.49	4.56±0.19	1186±115	820±115
	Bdx10228	Fg	7.02±0.58	6.49±0.26	1081±86 (78)	925±86
		CG	5.65±0.54	4.61±0.18	1227±126 (118)	779±126
Wall chancel, north chapel	Bdx10229	CG	6.22±0.55	4.60±0.18	1352±130	654±130
	Bdx10230	CG	5.55±0.48	4.12±0.17	1345±128	661±128

Tab. 1. Individual TL-dating results on bricks from St Philbert. The TL ages are given in years before 2006. Fg refers to polymineral fine grain technique and CG to the coarse grains of quartz one. Uncertainties are given at one sigma

tured ca. 9th century) and might have also used occasionally older salvaged materials. Later bricks suggest restoration of the church in the Romanesque period.

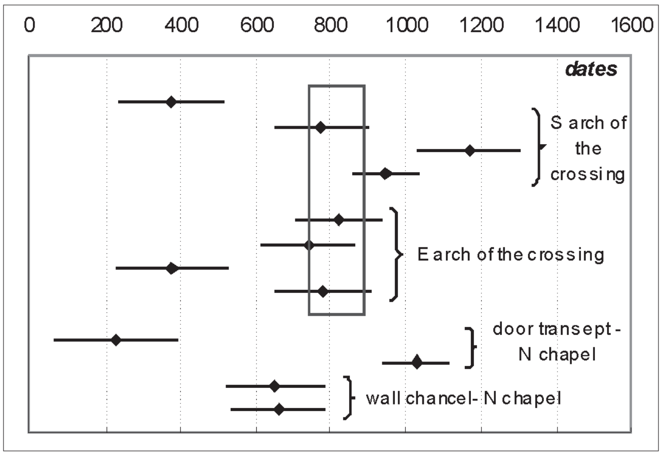

Fig. 3. Individual dating results on the 12 bricks sampled at St Philbert-de-Grandlieu: the square zone indicates the dating obtained by C14 on charcoals from mortar of the arches of the transept crossing

3.2. Saint-Martin of Angers

Located in the centre of the current town of Angers, the church is dedicated to Saint Martin (AD 316-397). The church, recently restored, shows a plan which consists of a square aisled nave, a gothic chancel and a large salient transept with a bell-tower at the crossing (Fig 4). The latter is built on four large pillars and arches decorated with bricks in the masonry made of limestone *moyen appareil* (Mallet, 1984, 23-4). On the basis of architectural analogies, the building of the crossing tower of Saint-Martin can be evaluated to have been done within the first half of the 11th century (Mallet, 1987, 596). Besides the typological indications, one of the few records relating to the church includes a charter of the famous Count of Anjou, Fulk III Nerra (987-1040), likely to date before 1020 (Hiret, 1608; Mussat, 1964).

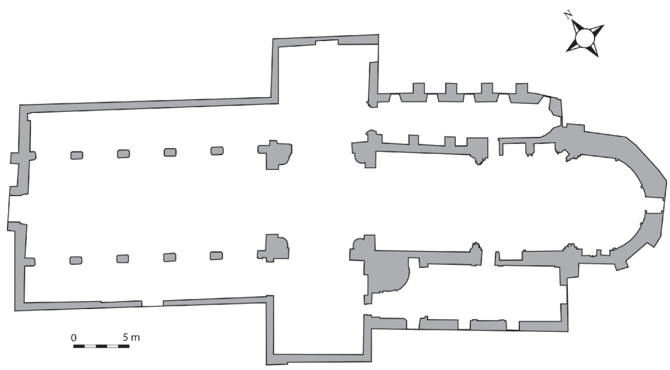

Fig. 4. Current plan of the church of St Martin in Angers (after G.Mester de Parajd & M.Iseppi)

The first to attribute the rebuilding of the church to the Count of Anjou is Gustave d'Espinay in 1870. Between 1929 and 1936, American archaeologist George Forsyth studied the church. Building on his work (Forsyth,

Location	Sample	Q (Gy) (fg technique)	I (mGy/yr)	Age (yrs) $\pm1\sigma_{tot}$ (σ_{stat})	Dates (AD) $\pm1\sigma_{tot}$
Western piers of the crossing tower	Bdx9456	10.91±0.47	10.11±0.53	1079±65 (47)	928±65
	Bdx9457	10.67±0.62	9.64±0.44	1107±79 (64)	900±79
	Bdx9459	11.66±0.53	9.86±0.46	1182±79 (59)	825±79
	Bdx9461	10.76±0.51	9.25±0.46	1163±82 (63)	844±82
	Bdx9472	12.38±0.64	9.74±0.42	1272±83 (66)	735±83
Buttress of the western facade	Bdx9462	10.99±0.60	9.71±0.42	1132±81 (63)	875±81

Tab. 2. Individual dating results of the bricks of St Martin's. TL ages are given in years before 2007 and the uncertainties, at one sigma.

1953), the study was completed in 2006 by Prigent and Hunot and a first phasing chronology of the site was proposed. The study indicates that the church was first built on a Roman road and a later villa (3rd century AD). After a short period of abandonment, the first Christian sanctuary was built and paved the way for a succession of four religious buildings on the site, the last being the subject of this study. Radiocarbon dating on charcoal from the mortar of the current church produced a date of 9th-10th century, which would give rise to debate concerning Fulk Nerra's intervention on the church (Prigent & Hunot, 2006).

The aim of this work is twofold. The first objective is to verify whether the CBM used in the building of the surviving church are reused Roman material from the remains of previous buildings on the site or whether they are early medieval productions as suggested by Forsyth in 1953. The homogeneity of the size, colour and fabric of these materials, together with differences observed when compared to the obvious Roman CBM found *in situ* during the excavation, would suggest medieval materials (Prigent, *pers. comm.*). The answer to this question is to be determined using luminescence dating applied on ceramic materials.

If it appears to be that the materials were made specifically for the purpose of the construction of the church, and assuming they were used shortly after manufacture, then dating the manufacture of the material would provide a date for the actual construction of the building. The second objective is therefore to shed light on the controversy surrounding the origin of the rebuilding and to verify whether Fulk Nerra's intervention encompassed the whole building or was limited to later reparation.

For the purpose of this study, five bricks from the transept crossing pillars and one from a surviving buttress of the remaining western façade were sampled. The samples were then prepared and analysed in the laboratory of Bordeaux following the standard preparation process of the polymineral fine grains technique and measured using TL. The final individual dates of manufacture range from AD 735±83 to AD 928±65 (Table 2). The dates as a group are homogeneous and the mean date calculated is AD 851±60 (Fig 5).

If the manufacture is considered to be contemporary with the construction of the building, placing the building of the church in the 9th century, this presents opposing evidence to the theory of Fulk Nerra being responsible for the whole construction.

This study highlights the importance of being cautious of written records and their interpretation, and also shows that the practise of brickmaking was not a forgotten skill in the early medieval period in Anjou. Indeed, the technique was favoured despite the local availability of Roman materials.

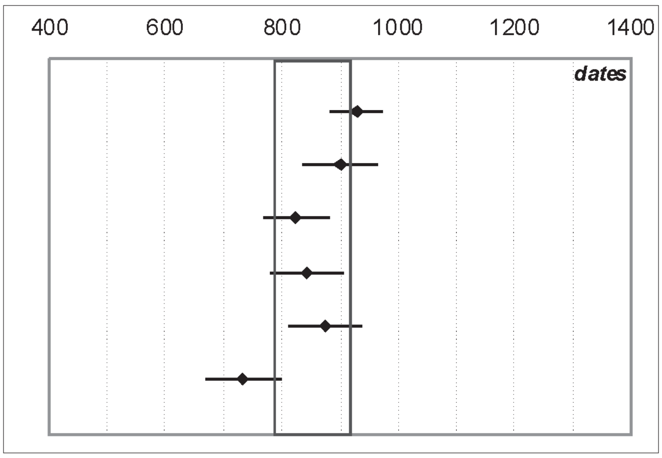

Fig. 5. Individual dating results and overall dating (square zone) of the bricks of St Martin, Angers

3.3. Notre-Dame-sous-Terre

Mont-Saint-Michel is a small, rocky island that lies in a shallow tidal bay between Normandy and Brittany in North-western France. In 966, the first official act passed by the Carolingian King Lothar (954-986) allowed the settlement of Benedictine monks on the island with their Abbot, Maynard 1st (965-991) who is likely to have been responsible for the construction of a main abbey on the top of the island, as well as the churches surrounding it. One of these churches, positioned to the west of the island, is known as Notre-Dame-Sous-Terre, the subject of this study. A 12th century cartulary, the *Introductio Monachrum,* describes how fire ravaged the main abbey and its churches in around AD 991-1009. The main abbey was repaired and enlarged, but the little church of Notre-Dame was preserved and used as a substructure for the new abbey. Thus, it became underground giving rise to the name by which it is known today. Being underground allowed it to be well preserved and is the reason why this small church constitutes today the only standing witness of the monastic origins of Mont-Saint-Michel.

The original building is rectangular in shape (13 × 11 m). The surrounding wall is punctuated by four windows. A median wall made of two arches splits the building into two naves, each with small sanctuaries at the eastern end (Fig 6). Above them is a tribune level. The masonry is made up of granite rubble (Sapin *et al.*, 2008) sometimes interrupted by bonding courses of brick. Bricks are also used to turn the round-headed arches. The building as a whole can be typologically evaluated as belonging to the second half of the 10th century (Baylé, 1997; 2000) from comparisons with buildings in the region displaying similar architectural features, along with evidence provided by written records.

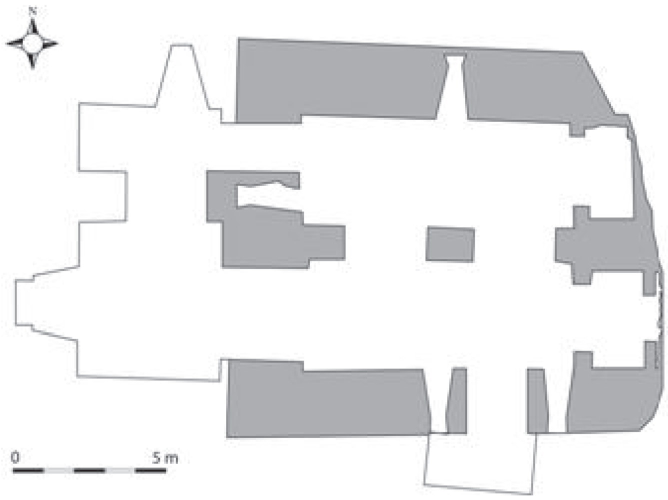

Fig. 6. Plan of the building (drawn by the CEM, in Sapin *et al*., 2008)

When considering the detailed phasing, several hypotheses have been raised since the first archaeological study of the building in the 1960's. The *Monuments Historiques* architect responsible for the first restoration of the church, Froidevaux, supposed that for liturgical reasons, the building was originally made of two distinct naves in order to imitate the famous sanctuary of Monte Gargano in Italy, the first sanctuary dedicated to St Michael in Western Europe (Froidevaux, 1961). However, fellow archaeologist and historian, de Bouärd, supposed that the early building was made of a unique rectangular room at the beginning of the 10th century, and that only later, at the beginning of the 11th century, was it divided by the median wall (de Bouärd, 1961). In 1998, new archaeological studies performed by the team of Sapin from the Centre d'Etudes Médiévales of Auxerre, revealed particularly that the median wall rested against the western wall of the surrounding building. Moreover, the composition of the mortar appeared to be different in the surrounding wall to that of the median wall. It was supposed, therefore, that a first phase would have been the building of the surrounding walls and that the median wall was added in a posterior phase. This division allowed the adjunction of the two eastern sanctuaries. However, no definitive date was proposed for the separate phases.

In order to attempt to provide further precision on the phasing of the church, TL dating was applied on the bricks of the church. However, a preliminary examination was necessary to check if the dated event is actually relating to manufacture, and not the late 10th- early 11th century fire mentioned by the cartularies. Since the mortar used to embed brick or stone also contains minerals, this material could be analysed by TL to determine whether it was affected by an historical firing or not. The TL results gave a geological date for the mortar, which means that the mortar, and by extension the church, was never affected by a fire strong enough to have altered the material. Consequently, the dated event was assured to be that of the manufacture.

The brick sampling strategy was designed in conjunction with archaeologists according to the historical and archaeological questions to be answered. Eight separate areas of masonry were sampled, taking one to four bricks from each structure. The paleodose was evaluated using an additive dose and regeneration procedure with quartz mainly a coarse grain (80-200µm) protocol but also the fine grain technique with some samples.

One of the results obtained from a single brick located on the second floor produced an older date than the rest. By applying the statistical $\div^2$ test we concluded that this result appeared to deviate significantly from the others. It was decided not to include it in the overall dating of the

Sample	Q (Gy) (CG technique)	I (mGy/yr)	Dates (AD) $\pm 1\sigma_{total}$	Structure	Dates(AD) $\pm 1\sigma_{total}$	Phase	Dates (AD) $\pm 1\sigma$
Bdx8853	4.26±0.50	4.02±0.15	947±131 (125)	Window n°65	985±68 (56)	1	952±47 (26)
Bdx8854	4.26±0.39	4.45±0.16	1049±93 (86)				
Bdx8856	4.62±0.40	4.37±0.16	947±100 (92)				
Bdx8866	4.14±0.31	3.88±0.15	941±89 (79)	Window n°66	941±89 (79)		
Bdx8861	4.29±0.29	4.05±0.18	946±85 (76)	Window n°62	958±52 (36)		
Bdx8862	4.08±0.16	3.91±0.15	962±75 (41)				
Bdx8858	4.24±0.39	4.10±0.15	916±86 (76)	Window n°73	899±80 (69)		
Bdx8859	4.99±0.69	4.26±0.16	832±168 (162)				
Bdx8864	4.89±0.33	4.46±0.17	952±75 (67)	apse n°27	1021±62 (50)	2	986±48 (31)
Bdx8865	5.71±0.40	5.46±0.21	985±85 (76)				
Bdx8863	4.23±0.30	4.45±0.17	954±75 (64)	apse n°22	954±75 (64)		
Bdx8851	4.83±0.36	4.72±0.18	994±75 (68)	Median wall	977±61 (50)		
Bdx8857	4.58±0.28	4.35±0.17	958±82 (73)				
Bdx8860	5.90±0.32	4.57±0.17	716±84 (70)	tribune	716±84 (70)	?	

Tab. 3. Weighted mean dates and related uncertainties, for each sample, each masonry structure and each phase

two building phases and it has been considered to be a re-used brick from a previous settlement on the island. Final TL dating results were averaged by building phase considering that all bricks of a given phase were contemporaneous (Table 3). The final results indicate that the primitive surrounding walls would have been made in AD 950±50 and that some decades later, probably around AD 990±50, the middle wall and the eastern apses would have been added (Fig 7). The results seem to be consistent with historical data when we consider that Maynard 1st is known to have arrived on the island in AD 965. The TL study tends to corroborate the archaeological building studies in confirming the existence of two phases. Moreover TL dating has been able to establish that the two phases were probably chronologically closer together than the archaeologist de Bouärd supposed when he separated the two phases by a century.

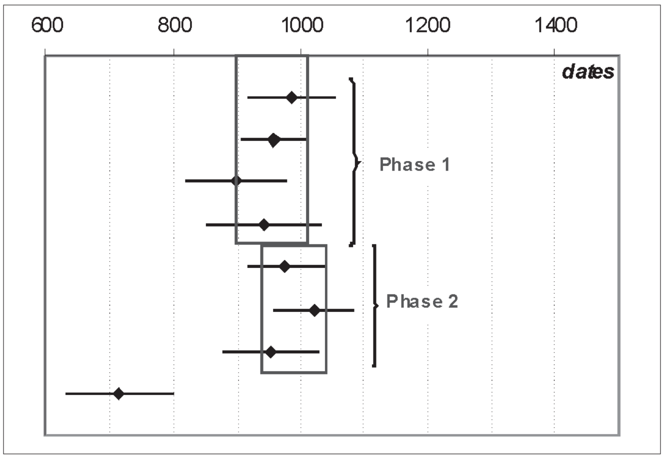

Fig. 7. Dating results for each masonry structure and each building phase (square zones) for Notre-Dame-sous-Terrre's church, Mont-Saint-Michel

3.4. Notre-Dame Outre l'Eau, Rugles

The town of Rugles is crossed by the River Risle and is located on the ancient road connecting Lisieux to Condé-sur-Iton, in the department of Eure, Normandy (Cliquet, 1993, 237). Located in the city centre of Rugles, on the eastern bank of the Risle, the little church, concerned by this study, is dedicated to Our Lady, the holy Virgin. The oldest written record of the church is a cartulary dated to the 1070's (Charpillon, 1870; Coutil, 1921, 63).

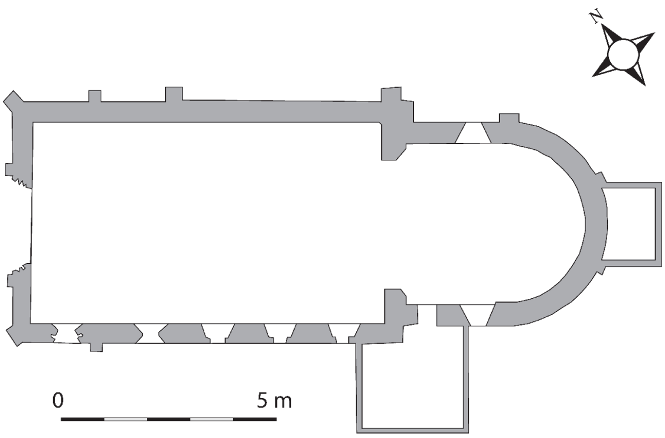

Fig. 8. Plan of the church Notre-Dame, Rugles (after Courtil, 1921)

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Location	Sample	Technique	Q (Gy)		I±? tot (mGy/yr) (model 2)		Dates ±1σ (model 2)	
			Bordeaux	Durham	Bordeaux	Durham	Bordeaux	Durham
chancel	Bdx11979 /Dur346-3	Fg (log)	6.92±0.58	-	4.53±0.07	-	481±199	-
		CG	6.26±0.71	5.54±0.19	2.51±0.16	2.51±0.12	-487±354	-162±179
upper northern nave	Bdx11982 /Dur346-1	Fg (log)	5.75±1.10	-	4.36±0.07	-	689±382	-
		CG	6.15±0.91	5.27±0.26	2.61±0.16	2.76±0.13	-350±441	117±154
lower northern nave	Bdx11983 /Dur346-2	Fg (log)	7.34±0.64	-	3.49 ±0.30	-	326±238	
		Fg (exp)	6.73±0.46	-			79±196	-
		CG	-	3.96±0.34	-	2.08±0.12	-	239±139

Tab. 4. Individual dates calculated for each sample.

The church displays a simple plan, consisting of a square nave and an apsidal chancel (Fig 8). It was mostly restored in the 16th and 17th centuries. However, the north wall of the nave and the chancel can be considered to be being mainly original. The fabric consists of small flint rubble and a number of horizontal rows of flat bricks. The fabric of the chancel also displays the use of square limestone rubble (Coutil, 1921, 65). In the upper part of the nave the suggestion of an *opus spicatum* underlined by rows of bricks can be seen (Baylé, 1992, 36-7). The foundation walls of the chancel are made of large, well-laid flints. The basis of the nave is also particularly well laid, built in a *grand appareil* (Coutil, 1921, 65). There is no surviving opening (neither original, nor later additions) in the north wall of the nave.

The aim of this work is to check the origin of the CBM. The evidence from the building (traces of *opus signinum* adhering to the surface of bricks, fragment of *tegulae* in the nave masonry and well cut rubble likely of Roman origin) and from the archaeological discoveries made under the floor of the church (Roman walls, the presence of CBM and other Roman materials such as columns (Coutil, 1921, 64; Delisle & Passy, 1862-9, III)) tend to suggest a Roman origin for these CBM.

Three bricks from the northern walls of the chancel and the nave of the church of Notre-Dame Outre-l'Eau were sampled. One of the sampled bricks from the chancel, had remains of Roman mortar on its lower surface. The second came from the upper part of the northern wall of the nave, within a section of herringbone pattern. The third brick sampled came from the lower part of this same wall.

To check the archaeological assumptions about the origin of the material, luminescence dating was performed on these three bricks. Furthermore, intercomparison studies were performed with the samples, in order to compare the dates obtained with different techniques, and also to evaluate whether the corrections applied for anomalous fading in fine grain data were valid for these materials.

The samples were divided into two and shared between the two laboratories of Bordeaux and Durham. Both polymineral fine grain (3-12 ìm) and coarse quartz grain (80-200 ìm) techniques were applied in the Bordeaux laboratory to determine the paleodose. The coarse quartz grain (90-150 ìm) technique was selected in the Durham laboratory (Bailiff, 2007).

Finally, after correction of the age following the two-phase dose-rate model, the final results on coarse grains vary from BC 487±354 to AD 689±382 for Bordeaux data and from BC 162±179 to AD 239±139 for Durham data (Table 4).

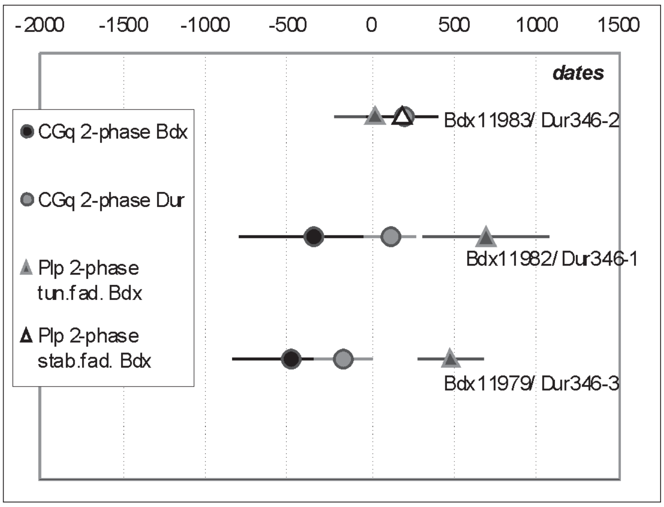

Fig. 9. Comparison of the Rugles dates obtained on polymineral fine grains and on coarse grains of quartz

The differences between the fine grain and the coarse grain data (Fig 9) are likely due to varying interpretations of the fading models: the traditional fading model not being applicable to all the samples, the uncertainties allocated to the experimental data, the difference in the evolution of the fading observed in the intercomparaison work. The difficulties in obtaining appropriate fading models have certainly presented problems when estimating a suitable age correction.

For the two samples Bdx11979/Dur346-3 and Bdx11982/Dur346-1, the results can be interpreted as re-used CBM from an earlier Roman building which is likely the case, especially for sample Bdx11979/Dur346-3 which shows pink Roman mortar on its surface. However, for sample Bdx 11983/Dur346-2, which comes from the lower part of the nave just above the *grand appareil* foundation wall, the bricks above are well laid and they could be considered as being in their primary position, i.e. they have not been displaced. In this case, a one-phase dose-rate model is appropriate and the date given by Durham is AD 194±102 on coarse grains. This would mean that this part of the building could be an original Roman wall dating to the 2nd or 3rd century AD. This interesting result should, however, be further investigated by an archaeological examination of the building masonries.

3.5. Condé-sur-Risle

The geostrategic location of the small parish of Condé-sur-Risle in the department of Eure, Normandy favoured the early settlement of human people. Situated on the banks of the river Risle on the crossing of the ancient road leading from Lisieux to Caudebec-en-Caux (Cliquet, 1993, 203), the remains of a supposed to be camp discovered on the archaeological site of les Grands Parquets (Coutil, 1904, 69-70), close to the churchyard, suggests settlement from the Roman period. The church itself is dedicated to Saint Martin and displays a simple rectangular plan with a fabric mainly composed of limestone and flints. The current church is the result of multiple re-building. This study is, however, focused on the original doorway of the nave, on the south side of the building. This doorway has jambs made of large, alternating, superimposed upright and horizontal limestone blocks, topped with a flat lintel likely consisting of a probable reused, re-cut Roman sarcophagus. The plain, round-headed tympanum filled with a *petit appareil* of limestone rubble is bordered by an alternation of stone and single or double tile voussoirs and hood-moulded with a range of square section billets suggesting a date in the 1030's. This would coincide with the first record of the parish in the 11th century when its first lord, Gilbert de Condé is mentioned (Bates, 1998, n° 166, 217). This original doorway has at some point been blocked up; probably done when the new doorway was added further west on the same side of the nave. This addition was most likely made in the 12th century as suggested by the zigzag of its tympanum and its Norman capitals assigned to the period 1120-30's (Clapham, 1936; Baylé, 1999).

The aim of this work is again to verify whether the CBM used in the original doorway is reused Roman material. The assumption that Roman material was reused appears very likely as the nearby archaeological excavations have revealed Roman activity (Cliquet, 1993). Moreover, the amount of CBM used in the original building is very limited (i.e., 19 in total) and their colour, matrix and size vary substantially, providing further evidence of salvaged materials.

Furthermore, intercomparison studies were performed with the samples divided between the laboratories of Durham and Bordeaux, comparing the dates obtained with the polymineral fine grain and coarse quartz grain techniques, and also evaluating whether the corrections applied for anomalous fading in fine grain data were valid for these materials.

Two of the three bricks (Bdx11984/Dur347-1 and Bdx11985/Dur347-2) from the original 11th century doorway of the nave were sampled. The samples were divided and analysed in the two laboratories.

In Bordeaux, the two techniques of polymineral fine grains (3-12µm) and coarse grains of quartz (80-200 µm) were performed where applicable. In Durham, SAR-OSL was performed with coarse grains of quartz (90-150 µm).

The final dates are AD 1029±62 and AD 1015±71 for fine grains and AD 23±130 and AD 66±120 for coarse grains according to Durham for Bdx11984/Dur347-1 and Bdx11985/Dur347-2 respectively and AD 313±138 for Bdx11984/Dur347-1 according to Bordeaux (Table 5).

This study highlights two salient points. Firstly, the importance of being cautious towards the use of polymineral fine grain materials which also require fading analysis as the proposed model can be inappropriate, giving rise to an underestimated correction of the age. Secondly, if only the results from the physical data are used, the archaeological question related to the origin of the CBM could not be answered at this stage, as the fine grain data give a date of the 11th century for manufacture and the coarse grains data, after correction of the dose rate using a two-phase model, provide dates of AD 244±136 and AD 225±136 according to Durham and AD 482±212 according to Bordeaux (Fig 10). However, if the archaeological evidence is taken into consideration, it can be deduced that the most accurate results are provided here by the coarse grains dating method.

Sample	Technique	Q (Gy)		$I \pm \sigma_{tot}$ (mGy/an)		Dates (AD) ±1σ	
		Bordeaux	Durham	Bordeaux	Durham	Bordeaux	Durham
Bdx11984 /Dur347-1	Fg (log)	8.95±0.47	-	9.14±0.05	-	1029±62	-
	CG	7.77±0.56	8.70±0.56	5.09±0.24 (model 2)	4.91±0.18 (model 2)	482±212 (model 2)	244±136 (model 2)
Bdx11985 /Dur347-2	Fg (log)	4.07±0.25	-	4.09±0.04	-	1017±76	-
	Fg (exp)	4.05±0.28	-			1012±68	-
	CG	-	4.68±0.46	-	2.62±0.11 (model 2)	-	225±136 (model 2)

Tab. 5. Individual dates calculated for each sample

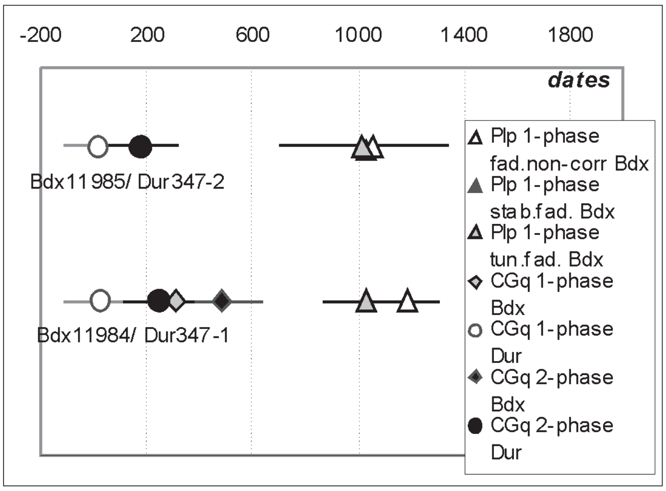

Fig. 10. Comparison of the Condé-sur-Risle dates obtained on polymineral fine grains and on coarse grains of quartz

3.6. Vieux-Pont-en-Auge

The parish of Vieux-Pont-en-Auge is located in the department of Calvados, Basse-Normandy, 30 km south-west of Lisieux, on the road joining the Anjou region to Lisieux. The church, dedicated to Saint Aubin, Bishop of Angers (529-550), has a basic plan comprising a modest rectangular nave (14 x 8 m) and a narrower rectangular chancel (8 x 5 m) (Fig 11). A bell-tower was added in the south corner formed by the nave and the chancel (Decaëns, 1987, 575). On its eastern wall, there is a stone slab with an obituary inscription assigned to the commissioner: Ranoldus (Beck, 1981, 75, 85-6). The building underwent later changes and partial restorations in the 16th, 18th and 19th centuries, particularly on the north side of the nave. The south nave, the chancel and the lower part of the tower are built in *petit appareil* alternating with horizontal rows of bricks (Musset, 1967, 43). Bricks are also used to turn the triple hood-moulding of the Romanesque windows on the nave and chancel (Decaëns, 1987, 575). The upper part of the tower is built in a *moyen appareil*. A notable feature of the church is the north corner between the nave and the chancel, which presents an alternation of flat and upright large limestone blocks evocative of the Anglo-Saxon long-and-short quoin (Baylé, *pers.comm.*).

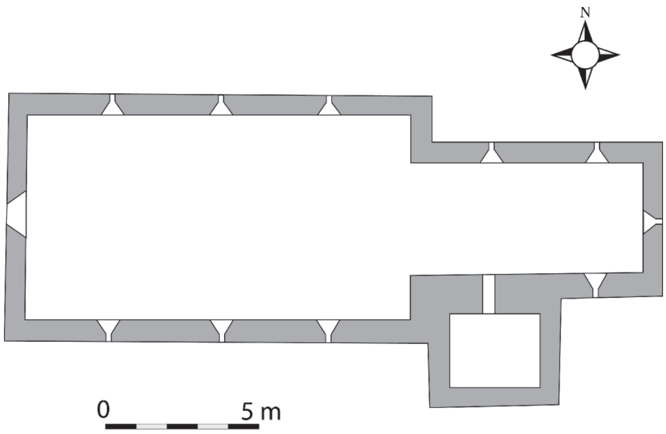

Fig. 11. Plan of the church Saint-Aubin in Vieux-Pont (after Caumont, 1867)

The building of the original church is likely to be prior to 1068, as the charter of St Désir's, Lisieux, established by William the Conqueror, records the repurchase of the Vieux-Pont church by the nuns of St Désir's (Bates, 1998, n°179). Moreover, the slab and its inscription can be typologically and epigraphically assigned to the first half of the 11th century (Musset, 1967, 44; Baylé, 2000, 7). Ranoldus is a common name in the 11th century; it also appears in the charter of Richard I during the rebuilding of Fécamp sanctuary and in Wace's records (1155) in which Ranoldus, Lord of Vieux-Pont is said to have participated in the battle of Hastings (Baylé, 2001). However, it cannot be determined whether this is the same person. Musset considers the construction of the church must be linked to the period of foundations commissioned by Richard II, placing the building around 1025 (Musset, 1967). Further confirmation comes from the brick-stone alternation of the church, a feature he assigned to the 11th century (Musset, 1967, 43). Baylé assigns the building of the upper part of the bell-tower to the 1060-70's, on the

Structure	Sample	Technique	Q (Gy)	I (mGy/yr) (model 2)	Date ±1σ_{tot} (model 2)
South nave	Bdx9624	FgQ	5.38±0.48	3.87±0.13	616±159
	Bdx9625	FgQ	8.01±0.78	4.25±0.16	122±238
	Bdx9626	CG	7.09±0.86	3.35±0.15	-111±326
Bell-tower	Bdx9628	FgQ	9.11±1.13	4.33±0.17	-100±327
North chancel	Bdx11987	CG	10.14±0.94	3.62±0.18	-794±356
	Bdx11989	CG	6.97±0.54	3.20±0.15	-170±247
		Fg	4.69±0.26	4.78±0.16(model 1)	1005±62 (model 1)

Tab. 6. Results of TL dating on Saint-Aubin's bricks. Uncertainties are given at one sigma.

basis of its stylistic similarities with the dated Abbaye-aux-Dames, Caen (Baylé, 2000, 7). As this part of the building is later than the rest of the church, it suggests a date for the primitive building of around 1030-40's. Finally, due to the absence of buttresses, Manoeuvrier assigns the building to the second half of the 10th century (Manoeuvrier, 1992). Moreover, he suggests the CBM used in the masonries could be early medieval as it is likely that, because of its inclination, the roof was covered with tiles rather than thatch. The making of tiles on or for the site tends to suggest they could have also been used for the walling (Manoeuvrier, 1999).

The aim of this study is to determine whether the bricks used in the masonry are early medieval as suggested by Manoeuvrier, or Roman as clues such as traces of *opus signinum* on bricks would tend to suggest.

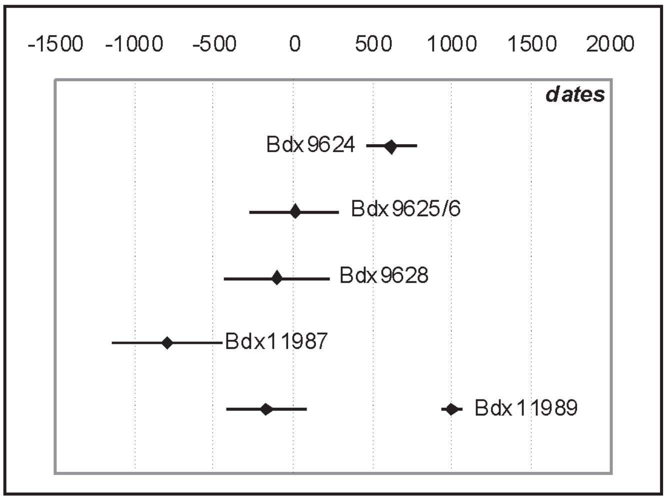

Fig. 12. Individual dates of the samples from the bricks taken in Vieux-Pont-en-Auge's

This work deals with two bricks sampled from the north wall of the chancel and four from the south wall of the nave. The quartz fine grain (fgQ) or the quartz coarse grain (CG) techniques were performed on these samples.

The final individual dates ranges from BC 794±356 to AD 616±159 after correction of the annual dose rate following a two-phase dose-rate model (Table 6). These results indicate the quartz ages are older than the polymineral fine grain age and in one case the two-phase dose rate model does not provide a correction that is sufficient enough to bring the two sets of dates into agreement (Fig 12). At this stage of the work, this anomalous result is not explained.

4. STUDY CASES OF ENGLAND

After an overview of the use of CBM in north-western France, our study focused on buildings of similar period in south-eastern England.

Brickmaking, introduced by the Romans to Britain, seems to have ceased following their departure and the subsequent arrival of Anglian, Saxon and Jutish settlers in the 5th century, to reappear only at the end of the 12th century with the introduction of continental monastic institutions in England. In spite of this supposed break in brickmaking, early medieval builders continued to use CBM, considered for a long time to be Roman reused material (Morrant, 1768). However, historical and archaeological evidence suggests the transition from Roman to Anglo-Saxon culture was not so abrupt but instead more progressive with a cultural mix of the two people (Laing & Laing, 1996). Indeed, Bede (HE) reveals that in the mid-5th century, Romans from Britain recruited Anglo-Saxon mercenaries to get rid of the Northern invaders. In exchange for protection, Anglo-Saxon warriors were granted lands in the east of the country. Moreover, a study by Härke (1990) on Anglo-Saxon cemeteries in Kent shows that almost half of the 5th-6th century skeletons were Britons and that Anglo-Saxon genes are modified by Britons between 7th and 9th centuries, the result of a process of peaceful cultural interaction rather than sudden and aggressive takeover. Romano-British and Anglo-Saxons lived together at the same time and in collaboration for several decades on British land, long enough to enable a transmission of technical know-how such as brickmaking.

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Moreover, contact with the continent is also evident. In the early Anglo-Saxon period, exchanges between south-east England and Merovingian France are especially visible. Kent, by its geographical situation, is particularly receptive to foreign ideas and influences, explaining the occurrence of Frankish objects in England, especially in graveyards goods (Geake, 1997). The precursor case of the 7th century foundations of Jarrow and Monkwearmouth in Northumbria by Benedict Biscop, who visited Gaul and recruited Gaulish masons and glassmakers also illustrates this influence. Although affinity between England and Merovingian France declines from the death of Frankish king Dagobert I, causing to the disappearance of Frankish objects in archaeological contexts (Geake, 1997), political and economic links recover with Carolingian world and develop throughout England (Lawson, 1991, 170). Through trade (Rosser, 1998; Lawson, 1991, 171), mixed weddings (Ortenberg, 1992, 229) and English scholars' activities in the Carolingian Empire (Campbell, 1978; Ortenberg, 1992, 228), continental technical know-how and craftsmen are reintroduced to the island. Links with continent are not limited to Carolingian Empire but spread also to the Mediterranean world particularly with the arrival of missionaries such as Augustine and Theodore.

With the knowledge of all these contacts in mind, together with the results of luminescence dating applied on CBM from Carolingian and pre-Romanesque sites obtained in the first part of this paper, it would be tempting to re-evaluate the question of brick/tile manufacture during the pre-Conquest period in England (Jope, 1964; Minter, 2006). In addition, there are several examples of decorative wall or floor tiles that have been discovered in late Anglo-Saxon religious contexts such as in York, Peterborough, Coventry, Canterbury, Winchester and in Westminster Abbey, London (Betts, 1986; Keen, 1993).

The aim is to extend the archaeological question, which started in France, to include pre-12th century buildings in England, in particular in the south-east including Essex and Kent.

For consistency, the study focuses primarily on buildings of similar status, i.e. religious, and of the same chronological period, between the 9th and 11th century. One exception is the case of St Martin's, Canterbury, whose particular interest is linked to the seniority of its use and the fact it is likely to have been an original Roman building reused in the Anglo-Saxon period.

A first inventory of churches from the period and area concerned is established by cross-matching bibliographical references, especially those provided by the three-volume *Anglo-Saxon Architecture* work by the Taylors (1965; 1978), the series of *Buildings of England* by Pevsner (1965), the *Royal Commission on the Historical Monuments of England* (RCHME*)* and the *Victoria County History* (VCH*)* architectural reports for each county. After an initial investigation on the field, churches were selected from the surveyed sites.

Some churches have been excluded from the dating study due to:

- low quantity of CBM;
- sporadic and haphazard use of the CBM;
- archaeological evidence for the origin of the material, e.g. artefacts showing evidence of reuse such as architectonic elements used in ways that they were not designed for, e.g. sculpted artefacts used as rubble in the masonry, pieces of pinkish mortar, characteristic of Roman mortar, stuck to CBM or used as building units (i.e. used like individual blocks, cf Lower Halstow).
- no Anglo-Saxon features identified;
- inaccessible/buried sites;
- unsuitable conditions for dating by luminescence, i.e. non-roofed remains, risk of water infiltration, problem for the dose rate;
- heavily restored or protected sites where obtaining the authorization to sample could have been too difficult.

The sites selected were the parish churches of St Martin's (Canterbury), Darenth, Lower Halstow, in Kent and Holy Trinity (Colchester) and Chipping Ongar in Essex.

The reasons for these choices were:

- large quantity of CBM used homogeneously and in an organised way (demonstrating a purposeful selection of the material; making the sampling easier);
- methodological interest: potentiality of luminescence for *spolia* dating;
- historical interest: in the case of St Martin (Canterbury), where this is the Roman building itself which is supposed to be reused (but where the material has not been moved), possibility of dating the original Roman building;

In most of the cases, preliminary examination of CBM used in Anglo-Saxon buildings tends to suggest a Roman origin of the material. In these cases, only one or two bricks are sampled for each site, in order to reduce the physical damage to the building, the aim being then to test only the archaeological presumption and not to accurately date the building. It is important to keep in mind that the dated event is the brickmaking moment and not the brick insertion into the masonry and that accurate dating of reused displaced material is not yet feasible. However, a first approximation can be proposed by applying the two-phase dose rate model as explained in the methodology.

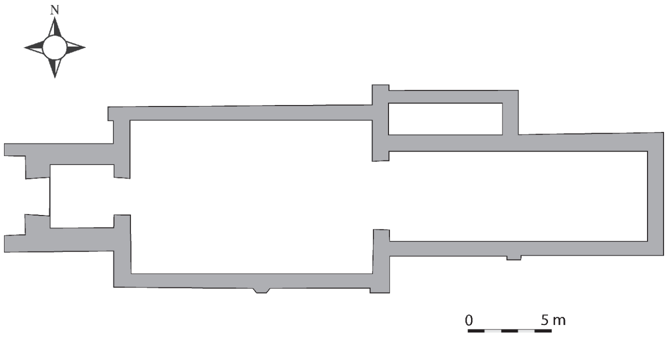

Fig. 13. Plan of the current church of St Martin, Canterbury (after Jenkins, 1965)

4.1. Saint-Martin, Canterbury

The small church is dedicated to Saint Martin of Tours (316-397), founder of the first minster in western Europe and bishop of Tours, whose cult was particularly renowned in Gaul during the Middle Ages. The church is located in the east part of the current city of Canterbury, just outside the Roman walls on top of a small hill that overlooks the ancient road leading to the Roman port of Richborough (Fisher, 1962, 355). This geostrategic position likely favoured early human settlements as archaeological excavations in the graveyard have revealed traces of occupation from the Iron Age (Lyle, 2002) and Canterbury becomes a *civitas* in the early 2nd century AD (Frere, 1965, 23-24; Cunliffe, 1969, 20). Historic texts report the existence of a church dedicated to St Martin to the east of the cathedral, such as Bede in 7th century (*HE*, I, 26; Colgrave & Mynors, 1969). Whether the church Bede mentioned is the current one has been a subject of debate (Taylor & Taylor, 1965, 143; Thomas, 1980; Tatton-Brown, 1980, 14; Bell, 2005, 124). Some scholars consider the church as the sanctuary salvaged by the Christian and Frankish queen of Ethelbert, Bertha from Tours, and her chaplain Liudhard, which would explain the dedication of the church. Augustine himself, welcomed by King Ethelbert, would have reused the oratory and made it a church (Clapham, 1930).

The church displays a basic plan: a square nave measuring 11x7 m adjacent to a square chancel of 6x4 m. These structures are considered as being original (Routledge, 1897) to which the bell-tower (14th century), the eastern extension of the chancel (13th century) and the vestry (Taylor & Taylor, 1965, 143) have been added subsequently (Fig 13).

For this study, the focus was on the south walls of the nave and the chancel as they are the original walls and are the most accessible and the least restored.

The fabric of the chancel, for its western part, is mainly made of CBM well laid in horizontal rows, alternating with flints, rubble of Marquise oolite and Calcaire Grossier (Worssam & Tatton-Brown, 1990) separated by thin joints. Two doors are now blocked: one, located in the western part of the wall, has a horizontal lintel probably made of a Roman sarcophagus and its jambs are made of CBM; it is assigned to the Roman period (Jenkins, 1965, 12). The second door, further to the east, is round headed with ragstone voussoirs and jambs made of CBM, and is assigned to the Saxon period (Taylor & Taylor, 1965, 144). A piece of Marquise stone in its western jamb displays a Saxon inscription. Later windows have been added to the original south wall of the chancel. The nave walls are built with small rubble containing local ragstone, tuff and flints (Taylor & Taylor, 1965, 143) and proportionally less CBM than in the chancel, laid in a more haphazard way.

The purpose of this work was to evaluate whether the bricks used in the different building phases of the church are Roman, as suspected by a number of scholars (Routledge, 1897; Tatton-Brown, 1980), or contemporary with the erection of the church.

Results of the luminescence measurements with coarse grains of quartz extracted from the 2 samples reveal that the date of manufacture obtained for the brick from the chancel and the brick from the nave indicate Roman origin. If both are considered to be reused from Roman structures located elsewhere and made of bricks of the same composition, a two-phase dose-rate model can be applied to correct the date. Using these adjustments, the chancel brick is dated to AD 119±122 (Table 7) and indicates manufacture between the 1st and the 3rd centuries AD which fits archaeologically with the settlements of the *civitas* of Canterbury. For the sample from the nave, also applying a two-phase dose-rate model, the corrected date is AD 323±117 (Table 7) which, if accurate, suggests it was amongst the last witnesses of Roman brickmaking in England before their departure at the beginning of the 5th century.

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Sample	Q±s.d. (Gy) (CG technique)	I ± σ_{tot} (mGy/yr) (model 2)	Age (yrs) ± σ_{tot} (σ_{stat}) (model 2)	Date ± σ_{tot} (AD) (model2)
345-1	6.43±0.40	3.40±0.10	1889±122 (62)	119±122
345-2	5.98±0.48	3.55±0.10	1685±117 (58)	323±117

Tab. 7. Results of the OSL dating of the bricks from St Martin's, Canterbury.

4.2. Saint-Margaret of Antioch, Lower Halstow

The church dedicated to Saint Margaret of Antioch is situated on an embankment on the river Medway estuary, in Lower Halstow, north Kent. The coastal location proved suitable for early settlement as is evident by the number of Roman remains noticed and described since the 18th century both in the graveyard of the church itself and in the vicinity (Smith, 1842, 226; Page, 1932, 117, 156; Newman, 1969; Bell, 2005). Although there is no mention of Lower Halstow in the *Domesday Book*, the church is, however, reported in the *Domesday Monachorum*, which confirms a church existed on the site around 1100.

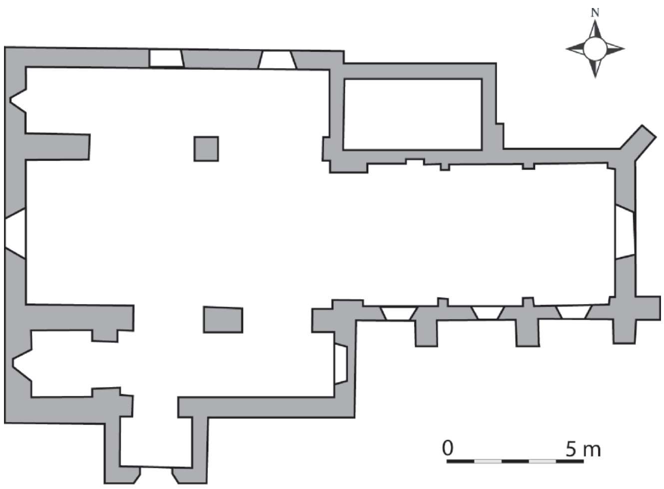

Fig. 14. Plan of the current church of St Margaret, Lower Halstow (after Olive, 1918)

The current church has a Norman aisled nave, a 13th century tower on the top of the western part of the south aisle, a 20th century porch, a modern north chapel and a square chancel (11 x 6 m) (Fig 14) assigned to the Anglo-Saxon period according to architectural features (Olive, 1918, 157; Taylor & Taylor, 1965, 281; Newman, 1969, 359). The walls are mainly erected with flints, blocks of clunch and a number of CBM (Baldwin-Brown, 1925, 456), especially in the south wall of the chancel. They can be found sporadically in the wall masonry and in a more organised way in the evocation of an *opus spicatum* in the lower parts of the wall. They are also observed in a vertical pileup in the western part of the wall where the herring bone pattern ends and finally, in a narrow and small opening, now blocked, in the upper part of the central wall.

Different types of fabric have been observed among the CBM, as well as a variety of sizes. Most of the CBM was used in a fragmentary state and some display traces of *opus signinum* still adhering their faces. Moreover, *imbrices* and *tegulae* have also been identified in the building of the wall. All this evidence tends to suggest a Roman origin for the CBM used in the building of the church.

The aim of this work is to re-examine the suspected Roman origin of the ceramic material used in the Anglo-Saxon construction. One sample was taken from the *opus spicatum.* The corrected date for the manufacture of this brick is AD 411±125 (Table 8) which is relatively late as at that time Romans were leaving Kent. This would be a one of the late witnesses of Roman brickmaking.

4.3. Saint-Margaret, Darenth

Situated on a hillside and crossed by the Darent river, the parish of Darenth is located in north western Kent, 20 km east of London and 3 km from the modern road (A2), which follows the ancient, Roman Watling Street (Elliston-Erwood, 1912, 83 ; Taylor & Taylor, 1965, 190). A 2nd – 4th century Roman palatial villa was excavated in 1894-5 and evidence suggests that after it was abandoned in 5th – 6th century, some parts were reoccupied by a Saxon wooden habitation (Payne, 1897; Philip, 1984). From the 7th – 8th century, a village settled 700 m north of the early Saxon settlements and developed into the current town (Philip, 1984).

Sample	Q±d.s. (Gy) (CG technique)	I ± σ_{tot} (mGy/yr) (model 2)	Age ± σ_{tot} (? stat) (years) (model2)	Date ± σ_{tot} (AD) (model 2)
344-2	5,59±0,77	3,50±0,13	1597±125 (87)	411±125

Tab. 8. Results of the OSL dating of the brick from Lower Halstow' church

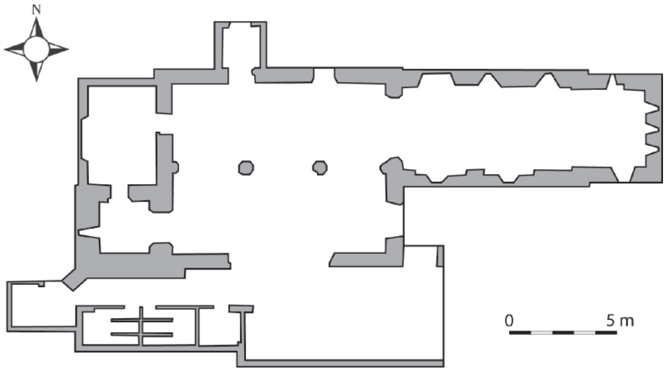

Fig. 15. Plan of the current church of St Margaret, Darenth (after G.AW.C)

500 m north of the Roman villa, a church was built almost certainly in the Saxon times and dedicated to Saint Margaret. Although there is little mention of the church before the 12th-century *Textus Roffensis* (1122-1124), the first reference to the site dates from AD 940 in a charter of Christchurch of Canterbury (Elliston-Erwood, 1912, 84). It refers to a manor in Darenth, which implicitly indicates the potential presence of an associated church. The site is also mentioned in the *Domesday Book* (Morris, 1983). Hence a church might have existed before the Conquest. Whether it was made of wood or stone and whether it corresponds to the current visible church is not known.

The church was the subject of a detailed study by Ellison-Erwood (1912, 83) and Taylor & Taylor also visited it (1965, I, 190), assigning it to the late Anglo-Saxon period (i.e. late 10th – early 11th century) on the basis of typological criteria. The church consists of a narrow nave, measuring 11 x 5 m and probably the only original remains of the primitive church, flanked with later additions such as the Norman square and narrow chancel, the 13th-century south aisle, the 13th-14th-century south western tower and the modern western vestry (Ellison-Erwood, 1912; Taylor & Taylor, 1965; Fig 15). The walls are mainly built of flint rubble with CBM found sporadically in the north and western wall of the nave and in a more organised way in the north-west, north-east and south-east quoins of the nave. Further CBM is evident as in the form of *opus spicatum* at the top of the western wall, below the gable, and in the round head and jambs of a blocked window, above the current north doorway.

The purpose of this case study is to verify whether the CBM is of Roman origin, as presented by Taylor & Taylor (1965) and Elliston-Erwood (1912) in their respective architectural descriptions of the church. Moreover, the local presence of available Roman building materials in large quantities due to the situation of the famous palatial villa of Darenth as well as other excavated villas in the region, such as the large villa of Lullingstone (8 km from Darenth; Meates, 1955), also suggests the possibility of Roman origin for these materials.

Luminescence measurements performed on one sample taken from the north-east quoin of the nave produced a Roman date for manufacture of the brick. Indeed, the corrected date for the manufacture of the brick is AD 333±118 (Table 9), which is also consistent with the period of Roman occupation of the neighbouring palatial villa.

Echantillon	Q±d.s. (Gy) (CG technique)	I± σ_{tot} (mGy/yr) (model2)	Age ± σ_{tot} (? stat) (years) (model 2)	Date ± σ_{tot} (AD) (model 2)
342-1 (53-90µm)	6,41±0,24	3,88±0,15	1651±115 (68)	357±115
342-1 (150-355µm)	6,25±0,37	3,68±0,14	1700±120 (75)	308±120
		Mean	1676±72	333±118

Tab. 9. Results of the OSL dating of two grain sizes of the brick from Darenth's church, and final mean.

4.4. Holy Trinity, Colchester

The church of Holy Trinity was likely built in the late Anglo-Saxon period, in the centre of the town of Colchester (Fisher, 1962, 345; Taylor & Taylor, 1965, 163; Rodwell & Rodwell, 1977, 106). Despite the earlier mention of the church is not before 1170, when the advowson of the church is disputed between the abbot of Bury St Edmund's abbey and the dean of Colchester (Cooper & Erlington, 1994, 312), the study of the parish boundaries of Colchester by Crummy (1974), the discovery of walls from an earlier church under the floor of the

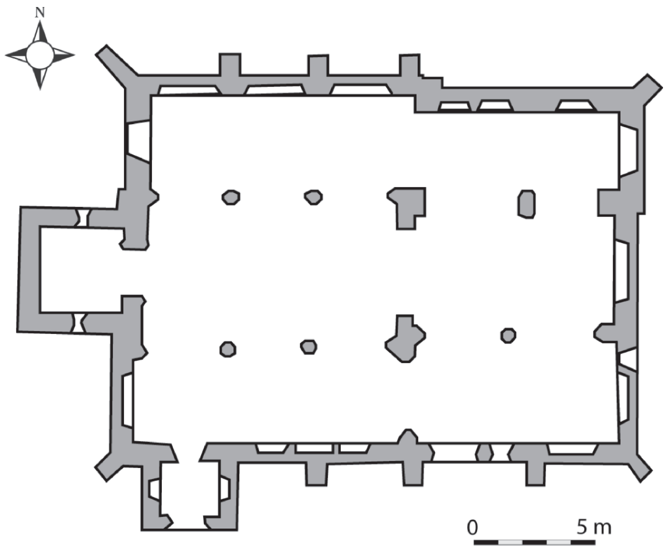

Fig. 16. Plan of the current church (after RCHM, 1921, 34)

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current nave (Rodwell & Rodwell, 1977, 106) and the architectural features of the original parts of the church (Rodwell & Rodwell, 1977, 106; Taylor and Taylor, 1965, 163) suggest the building of the earlier church be assigned to the 9th or 10th century.

The walls of the western square tower (Fig 16), the only surviving remains of the Anglo-Saxon church, are made of flint and *septaria* rubble, interrupted by horizontal rows of CBM. CBM have also been used to erect the triangular headed western doorway (Taylor and Taylor, 1965, 163). Brickmaker Minter has suggested the possibility that the CBM in Holy Trinity could be of Anglo-Saxon origin (Minter *et al.,* 2006). However the presence of *opus signinum* still adhering on the face of some bricks, and in some cases traces of digitations on the surface and the fragmentary state of some of the CBM rather suggest salvaged Roman materials. Hence the aim of this work was to obtain better chronological information concerning origin of the ceramic material used in the erection of the Anglo-Saxon tower of Holy Trinity.

One brick from the southern jamb of the internal western doorway was sampled and analysed in the Durham laboratory. The results of the analysis confirm the Roman origin of the brick. The estimated manufacture of the brick is AD 136±139 (Table 10). This date fits with the historical data of Colchester as it corresponds to the flourishing Roman period of the town.

Sample	Q±d.s. (Gy) (CG technique)	I ± σ_{tot} (mGy/yr) (model 2)	Age ± σ_{tot} (? stat) (years) (model 2)	Date ± σ_{tot} (AD) (model 2)
343-2	6.65±0.63	3.55±0.15	1872±139 (93)	136±139

Tab. 10 Results of the OSL dating of the brick from Holy Trinity's, Colchester.

4.5. Saint-Martin of Tours, Chipping Ongar

The town of Chipping Ongar is located 20 km east of Chelmsford in Essex. Early human settlements since at least the Roman period have been reported (Muilman, 1770, 316-7; Gough, 1789, 51; Wright, 1836, 330). The importance of the town increased in the Anglo-Saxon period when Chipping Ongar developed as a market town and became the administrative centre of the Saxon Hundred (Powell, 1956, 155). A fortress was built at this time to protect the town. A «motte and bailey» castle was built in the 11th or 12th century (Powell, 1956, 155) of which there is only one small fragment of surviving flint masonry. The earliest reference to Ongar was in 1043-5, in the will of Thurston, son of Wine, in which it is indicated that the manor of Ongar is held by his wife Æthelgyth. She is later also mentioned in the Domesday Book (Powell, 1956, 159). The manor was then passed to the priest Ingelric, and from 1086, to his successor, Eustace, count of Boulogne, an important Essex landowner, who strengthened the Saxon defence. The castle was also enlarged and became the Caput of the count's Essex fief (Powell, 1956, 159). It then passed to the hands of his daughter Matilda as a dowry for her wedding to Stephen, count of Blois, future King of England (Morant, 1768; RCHM, 1921). It was Matilda who also granted Coggeshall abbey land to the Savignac order in 1140. In 1154, the son of Matilda and Stephen, William, Earl of Surrey, granted the manor of Chipping Ongar to a powerful man, right hand of the heart of government, Richard de Lucy, the future Justiciar of Henry II (who himself visited the castle in 1154).

The fact that a manor is mentioned implicitly suggests the existence of an associated church, as most parish churches in Essex originated as manorial churches and the church is usually close to the site of an ancient manor house whose lord possessed the advowson. It can be supposed then that a church existed in Chipping Ongar at least since the Saxo-Norman period. However, there are currently no known surviving historic sources related to the origins of the church building itself.

The church is made of a long and narrow nave (18 x 7 m) with a south aisle added in 1884 during restoration works, a western modern porch and a bell-tower on the top of the western part of the nave, a square, long and narrow chancel (9 x 5.5 m) with a modern vestry on the western part of its north wall (RCHM, 1921, 51-2; Fig 17). The walls are made of well-laid flint rubbles and a single row of CBM. CBM is also present in quoins and the original south doorway, which has subsequently been blocked.

Some traces of the original windows are still visible in the eastern parts of the north and south walls of the

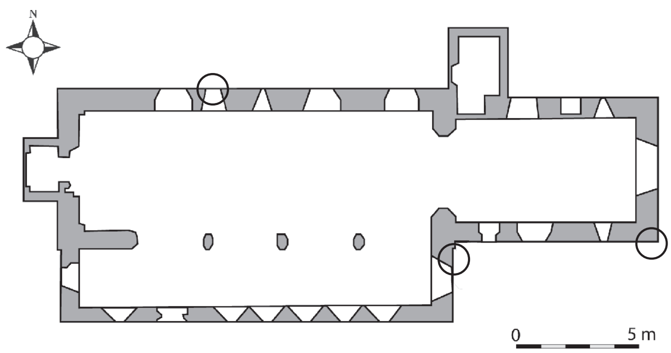

Fig. 17. Current plan of the church of St Martin of Tours, Chipping Ongar (after RCHME, 1921, 52) ; the circles indicate the sampling locations

Sample	Q±d.s. (Gy) (CG technique)	I ± σ_{tot} (mGy/yr)	Age ± σ_{tot} (? $_{stat}$) (years)	Date ± σ_{tot} (AD)	Dating range
363-1A	2.98±0.15	3.20±0.08	931±57 (25)	1077±57	1020-1134
363-1B	3.08±0.14	3.19±0.08	965±59 (25)	1043±59	984-1102
363-2A	2.86±0.12	2.91±0.07	983±61 (25)	1025±61	964-1086
363-3	3.08±0.08	3.06±0.07	1003±58 (23)	1005±58	947-1063

Tab. 11. Results of the OSL dating of the bricks from Chipping Ongar's church.

chancel, as well as in the north wall of the nave, allowing us to assign the earlier building to the Norman architecture (Powell, 1956, 163).

Four bricks were sampled in three different locations of the church: two samples come from the blocked south nave doorway, a brick in the junction between the north wall of the chancel and the east recess wall of the south nave and another one in the south east quoin of the chancel. The objective of the study is to verify the origin of the brickmaking as the CBM has often been described as re-used Roman brick. This view is based on the Roman archaeological remains discovered in the 18th century in the graveyard of the parish (Muilman, 1770, 316-7; Gough, 1789, 51; Wright, 1836, 330), and the assumption that Roman building materials would therefore have been available for the building of the church. However, based on typological criteria, Rodwell, Drury (2000) and Ryan (1996) do not identify the bricks as being Roman and have not been able to link them with any other known type from Essex. Despite the link between Chipping Ongar and Coggeshall, the bricks are not comparable to the «great bricks» either. Therefore, the question still remains whether the CBM from Chipping Ongar are Roman or later.

The luminescence results for the four bricks have provided final ages comprise between 931±25 and 1003±23 years and a mean date of AD 1038±32 for the manufacture of these materials (Table 11; Fig 18). This result is particularly interesting as no wall brick of this date has been identified previously in England. The fact that the bricks cannot be associated to any known type in Essex and the strong link of the parish with its Norman owners raises the question of the provenance of these bricks. Moreover, most of the CBM used were in a fragmentary state and they are of various sizes (however, their colour and texture are very homogeneous). These characteristics could constitute evidence of displaced bricks from the same batch, imported from a long distance, explaining their broken state. It is possible that the bricks were not made, in the first instance, with the aim of building the church but instead might have been brought for the construction of another building and the remainder used for the church. This would explain why they are purposefully and efficiently used jointly in the architectural features (i.e. doors, rows, quoins) with the excess of the material used as haphazard, independent rubble in the masonry. However, this interpretation remains hypothetical and further work should be done on other buildings showing similar bricks.

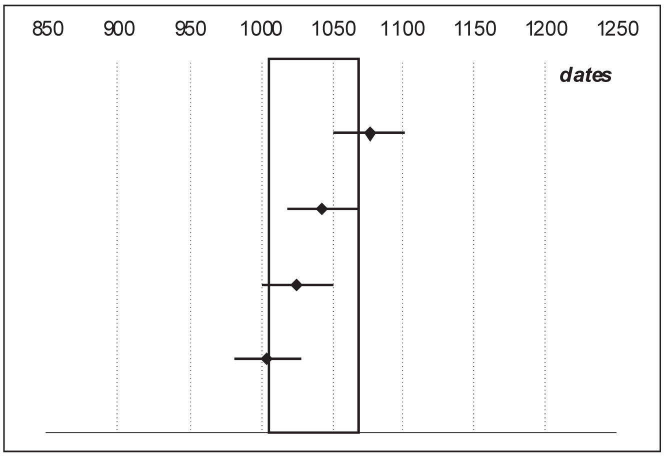

Fig. 18. Individual dating results and overall dating (square zone) from the bricks of St Martin of Tours' church, Chipping Ongar

5. DISCUSSION

The overall aims of this study were to evaluate the potential viability of luminescence dating as a tool for building archaeology and in so doing, to re-address the long-standing theories surrounding the reuse of Roman *spolia* on medieval building sites. A series of 11 sites were selected based on the need for chronological re-evaluation of the origin of the building materials, the edification of the building itself and even intermediate building phases. Architectural similarities observed between France and England, even before the Norman Conquest, naturally led to an investigation into the origin and the mode of use of ceramic building materials.

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5.1. Results of luminescence dating applied to CBM from early medieval churches

This study has shown that the luminescence dating techniques can be routinely applied on ceramic archaeological artefacts. The results from this study can be categorized into three groups.

1. Cases where the scientific results are in good agreement with archaeological assumptions and/or bringing further information: the study of the Collegiate of Saint-Martin in Angers, for which the bell-tower was erected in the 9th century (AD 850±60); the study of the church Notre-Dame-sous-Terre which allowed defining, in conjunction with the archaeological data, the identification of two building phases in the late 10th century (AD 950±50 for the surrounding walls and AD 990±50 for the eastern sanctuaries and the median wall); the study of the parish church of St Martin of Tours, Chipping Ongar, where the bricks sampled (AD 1040±30) appeared to be of early medieval manufacture produced slightly prior the Conquest.

2. Cases where the results of luminescence dating applied to CBM provided confirmation including situations where there was a question relating to reused materials based on archaeological assessment. The study highlighted the practice of Roman bricks used in the walls of Anglo-Saxon churches such as in St Martin in Canterbury, St Margaret of Antioch in Lower Halstow, St Margaret in Darenth and Holy Trinity in Colchester, or in pre-Romanesque masonries in France, in the parish churches of St Aubin in Vieux-Pont-en-Auge, St Martin in Condé-sur-Risle or Notre-Dame-Outre-l'Eau in Rugles. In the case of reused materials, the uncertainty in the luminescence date (of manufacture) is increased because of uncertainty in the gamma component of the annual dose rate with each displacement. However, it was possible to estimate a date of manufacture for these materials with a corrected dose rate (Bailiff, 2008). The model involved in this correction is based on the assumption of a provenance from a Roman structure made of mortar and bricks of the same composition as the analysed brick sample. Since this was a working hypothesis, uncertainties of 20-25% were assigned to the calculation of the gamma dose rate. Typically the effect of this correction on the age falls within a range from 2.6 to 6.7 %.

3. Cases, notably, St Philbert-de-Grandlieu, where the application of luminescence dating was unsatisfactory when applied to material judged on the basis of archaeological observations to be coeval. The scientific results were relatively highly dispersed and did not allow a manufacture date for these materials to be defined with a relative error comparable to those obtained in Case 1 and 2 types. The origin of the problem in the particular case of St Philbert is due to the heterogeneity of the ceramic fabric making it radiochemically complex.

To conclude, this study provides a better estimation of the advantages and disadvantages of the method and has led to an improvement of the protocols used to date CBM. As a result of this work the method can, in theory, be applied routinely providing the materials being analysed are themselves suitable. Indeed, data provided by luminescence dating for a homogeneous material found in its primary position are reliable. However, for a heterogeneous material or a displaced object, the situation is more complex and the limitations of luminescence dating applied to such contexts needs to be recognised.

5.2. Contribution to history of architecture between the 9th and 11th century

Besides the methodological improvements achieved within this work, the study has aimed to contribute to an improved understanding of architectural history and techniques used between the 9th and the 11th century in north-west France and south-east England.

In cases where CBM appears to be contemporary to the early medieval building, results from the chronological study of the building material not only allows the positioning of key-sites in the chronology of the history of art to be clarified, but also for established historical interpretations to be re-evaluated.

In the case of the detailed scientific analysis of ceramic samples from the St Philbert-de-Grandlieu abbey church, the building origin and phasing could not be clarified any further. However, the data obtained for the bricks (albeit with their technical limitations) suggest an early medieval origin for their manufacture rather than a practice of Roman reuse.

Conversely, the study of St Martin's Collegiate church, in Angers, enabled the dating of the lower parts of the crossing tower and of the western façade to be re-evaluated to the 9th century. This new chronological information has implications, not only concerning previous historic-political knowledge, but also on the evolution of the history of architecture. The construction of this part of the building can no longer be attributed to the famous Count of Anjou, Fulk Nerra. Indeed, his contribution to the rebuilding of the church should now be limited to other parts of the building. This chronological re-evaluation could potentially grant renewed significance to the Anjou province in the early Middle Age.

The influence of Anjou spread to Normandy, particularly in the 10th and 11th centuries, where the architecture of more humble buildings tends to imitate those seen in Anjou, most notably in the mode of use of CBM in the masonry. This could well be the case for other buildings studied in this thesis such as the parish churches of Vieux-Pont-en-Auge, Rugles or Condé-sur-Risle, if the preliminary dating for these sites from typological and historical data is accepted, and especially the church of Notre-Dame-sous-Terre, in Mont-Saint-Michel, where the dating study showed it was built after St Martin of Angers for instance. Moreover, the chronological data, used in conjunction with the archaeological interpretation of Notre-Dame-sous-Terre, allowed the gap separating the two building phases to be defined (a couple of decades) and enabled one clear hypothesis to stand out amongst the many controversial claims made for this particular site.

This study also provided the opportunity to examine the links between Normandy and England through case studies. Several sites seemed to reveal foreign architectural influences, such as Vieux-Pont-en-Auge where Baylé had already raised the hypothesis of a relationship with the Saxon world on the basis of a possible evocation of «long-and-short» work in the masonry. Similarly, in England, a number of churches shows a Norman influence. This can be seen at Boreham (Essex) for example, where the arch of the early chancel displays an alternation of brick and stone voussoirs. Although the origin of this type of architectural decoration is Roman or Byzantine, it is the only known example in the Anglo-Saxon world. However, examples of this kind are common in France, especially in the north west of the country. Is the pattern of the Boreham arch due to Norman influence prior to the Conquest? Taylor & Taylor (1965) assign the arch to the Anglo-Saxon period, before being blocked when the early chancel is turned into a Norman crossing tower. The CBM used as voussoirs in the arch is likely reused Roman material on the basis of a *tegula* identified amongst the voussoirs and because the variety of size, colour and fabric of the surveyed CBM suggests salvaged material. This information does not, however, provide any real evidence for the arch being Norman, as the Anglo-Saxons also resorted to reused Roman materials.

Another example of Anglo-French relations is the Chipping Ongar church, where the CBM cannot be attached to any known type and are of medieval manufacture according to the OSL results. The variations in size, the large number of fragmentary CBM, even used in the structural features of the church, and the sporadic use of other bricks tends to suggest the use of an excess of imported materials. Moreover, Chipping Ongar is one of the few sites in England where bricks are used in a continuous and regular way all over the building, a feature which is, however, more usual in France. Ownership of the church itself is linked with the Norman Duchy and its allies. Furthermore, using typological criteria, the church is assigned to the Norman style of architecture and dedicated to Saint Martin of Tours, whose cult was particularly fervent in medieval France. Finally, the OSL dating suggests a prior to or near Conquest origin for the brickmaking. All this evidence reinforces the idea of a connection with the Continent. Therefore, it is possible that the bricks are an example of early, post-Roman CBM in England, similar to but earlier than the «great bricks», or imported material from the Continent. These surprising results warrant the study to be developed to other contemporary cases isolated in Essex and displaying the same kind of unidentified bricks (Ryan, 1996). These new data casts some doubt on the pioneering role of Cistercians in the technological reintroduction of brickmaking in England and is in agreement with the recent works of Ryan (1996), Andrews (2008) and Rodwell (1998) which showed that the early post-Roman bricks could have actually been prior Cistercian or Flemish imports.

6. CONCLUSIONS

The role of chronometry in building archaeology is to position temporally as accurately as possible key-buildings as they constitute technological and stylistic markers of their time and are used to build the relative chronology of medieval architecture. This can be provided by the luminescence dating of CBM which allows the architectural structures related to these cultural features to be dated, the basis of architectural chronology. Moreover, these early buildings have likely been reused, restored, modified and transformed, which raises further archaeological questions and problems. However, defining different building phases is often difficult and providing a date for these phases of construction enables the evolution of the building to be better understood. Finally, the study of these buildings and in particular, dating their materials, provides further evidence relating to aesthetic and economic practices and to the human choices responsible for this architectural choice.

Looking forward, it is important to mention a technique which is still in development referred as Surface OSL (Liritzis, 1994; Habermann *et al.,* 2000; Greilich *et al.,* 2002; Greilich, 2004; Liritzis and Vafiadou, 2005;

Vieillevigne *et al.,* 2006; Vafiadou *et al.,* 2007). Whilst the event dated in this body of work is the last firing of the ceramic material, the Surface OSL technique attempts to date the last exposure of the brick surface to light. As such, it would be possible to obtain a date for the embedding of the brick in the masonry and hence, provide means of dating the use of the brick in construction of the building. Surface OSL is the next step in developing the application of physical dating methods to building archaeology.

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