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ORIGINAL ARTICLE

The Choice of Local or Imported Building Stone in English Medieval Churches; A South Cambridgeshire Case Study

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Abstract
External building stone has been recorded in 124 medieval churches in a 1200 km^2 area in south Cambridgeshire, UK. Each component (e.g. walling, windows, doors) in each architectural part (e.g. tower, nave, aisles, chancel) of each church has been separately recorded, generating over 2000 records of construction or repair projects. Every project has been dated from documentary records or architectural style, allowing analysis of stone use in both space and time. The pre-Reformation churches of the area mostly have rubble walls of local Fieldstone and Clunch (Cretaceous Chalk), and imported Jurassic limestone from Barnack, 60 km to the northwest. Less common are ashlar walls of Clunch or Barnack. The medieval dressings clearly show the use of local Clunch in less exposed positions but of the weather-resistant imported Barnack stone for exposed locations. This use of Barnack was despite the transport costs for the circuitous inland waterway journey of about 110 km. The amount of imported Barnack stone in windows and doors is probably a good indicator of a church's medieval wealth. Dressings of Clunch were much repaired or wholly replaced during the nineteenth century church 'restorations.' The replacement stone came mostly from the Jurassic Lincolnshire Limestone belt, not from Barnack but from other quarries along its outcrop from Weldon to Ancaster. The methodology of data collection, analysis and presentation in the Cambridgeshire study should prove useful for other heritage buildings nationally and internationally.

Keyword Jurassic · Barnack · Clunch · Fieldstone · Flint rubble

Introduction and Previous Work

This study explores quantitatively the influence of local geology on the spatial patterns of building stone use in one area through time, but especially through the High and Late Middle Ages (1000–1550). The study builds on the work of Woodcock and Furness (2021) on the history of stone use within the city of Cambridge. The Cambridge study encompassed all buildings using significant stone, excepting only domestic housing. However, in the surrounding rural area of south Cambridgeshire, the record of medieval stone use is mostly preserved in the now-Anglican parish churches with medieval origins.

The variation of architectural style across England and Wales has long been appreciated (e.g. Atkinson 1947). However the influence on that style of local building materials was only properly analysed in Alec Clifton-Taylor's seminal *Pattern of English building* (1972). Whilst Atkinson had focussed on churches, Clifton-Taylor concentrated on houses, because they show the full range of building materials other than stone. The later book by Clifton-Taylor and Ireson (1983) drew relatively more examples from churches, but there remained the need for more rigorous studies.

One such study is the Strategic Stone Survey of England, carried out jointly by the British Geological Survey and Historic England. This study has produced a database of quarry locations, stone types and example buildings, now known as the Building Stones Database for England, and accessed through a GIS interface (Historic England 2023a). Additionally, popular guides are available online for each county, linking example buildings to their source quarries and landscape areas. The guides relevant to the present study are those for Cambridgeshire (Historic England 2023b), Essex (Historic England 2023c) and Suffolk (Historic England 2023d). This large stone study is a major advance in charting the regional variations in building stone, very much in the spirit of Clifton-Taylor's work. However, it emphasises

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spatial patterns rather than how and why stone use changed through time.

A more detailed study of building stone in Norfolk by John Allen (2004) was exemplary in its quantitative approach to recording and displaying stone distribution and history, but focussed on nineteenth century buildings, with very little attention to churches. The same reservation applies to Allen's studies in Berkshire and Hampshire (Allen 2009, 2012, 2019).

Another localised, detailed survey of building materials in relation to geology is John Potter's work on the churches in the London Basin, the Paleogene and Neogene area rimmed by the Upper Cretaceous Chalk uplands. Potter's earlier papers covered in turn some of the distinctive geological components of London Basin churches; Silcretes (Potter 1998), Septaria (Potter 2000a), Travertine (Potter 2000b), Ferricrete (Potter 2001a), Roman brick and tile (Potter 2001b), and Bunter quartzite Cobbles (Potter 2002). Potter controversially proposed that incorporation of Ferricrete – Quaternary river gravel cemented by iron oxide – in rubble walls indicated an Anglo-Saxon construction date. This proposal implied a much greater amount of surviving Anglo-Saxon church walling in the London Basin than conventionally accepted, a proposal disputed by Hinton (Hinton 2002; Potter 2003). In part to support his Anglo-Saxon hypothesis, Potter turned his attention to the spatial patterns that early masons created in quoins, pilasters and walling (e.g. Potter 2005a, b, 2008, 2011). Overall, despite his voluminous output on London Basin churches, Potter's preoccupation with proving the Anglo-Saxon date of masonry has made it difficult to extract a more complete history of stone use in later medieval churches.

Most recently, the iron-rich sandstones and conglomerates in church walling in the present study area have been analysed (Woodcock 2025).

The present study has four main aims:

a) To map the spatial pattern of building stone use in south Cambridgeshire.
b) To investigate any geological control on this pattern.
c) To establish the sequence of use of different building stones through time.
d) To interpret this temporal pattern of stone use, particularly why the use of some stones ceased and why others gained favour.

Survey Area Location and Geology

The study area in eastern England (Fig. 1a) is a rectangle aligned southwest to northeast, chosen to include the cities of Cambridge and Ely. The rectangle is 40 kms long and 30 kms wide. It lies mostly within south Cambridgeshire, with small overlaps into Suffolk to the east and into the historic county of Huntingdonshire to the northwest. The long edge of the rectangle is deliberately parallel to the NE-SW strike of the Upper Jurassic to Upper Cretaceous bedrock (Fig. 1a, 2a). Within the study area there are 124 churches that contain a significant component of external medieval stonework (listed in Appendix A, locations in Fig. 2a). Of these, five are in Huntingdonshire (Bluntisham, Fenstanton, Hilton, Holywell and Yelling) and four are in Suffolk (Exning, Freckenham, Moulton and Worlington). The 115 Cambridgeshire medieval churches compare with an estimated 176 such churches in the whole county (Bradley and Pevsner 2014).

The area's bedrock stratigraphic succession (Fig. 2d) comprises Jurassic and Lower Cretaceous clays overlain by the increasingly calcareous Grey and White Chalk. The clays are interrupted by two thin coarser-grained units separated by an unconformity: the Upper Jurassic West Walton Formation and the Lower Cretaceous Woburn Sands Formation. The regional sequence dips gently to the southeast, exposing Jurassic rocks to the northwest and Upper Cretaceous rocks to the southeast (Fig. 2a). The local bedrock building stones come from two main units: a) hard bands in the Grey and White Chalk around Barrington in the southwest, around (Cherry) Hinton, Reach and Burwell, and around Isleham in the northeast (Fig. 1), and b) harder horizons of the Woburn Sands at Ely (Fig. 2a).

The superficial Quaternary deposits of the study area (Fig. 2b) comprise glacial tills in the west and southeast, alluvial sands and gravels mostly related to present and past courses of the River Cam, and spreads of peat in the low-lying Fenland in the north. The alluvium and till yield Fieldstone, much of it rich in Field Flint, which is much used for rubble walls in the area.

Main Stone Types and their Provenance

The stone of all external walling and dressings has been recorded and photographed in each of the 124 medieval churches in the study area. Stone has been identified and assigned to a source cluster of quarries or at least to a source region. The main stones are shown in their stratigraphical context in Fig. 3. They are illustrated on Figs. 4, 5 and 6, grouped as to whether they are from a local or distant source and whether their use is medieval and/or post medieval.

Locally Sourced Stone and Brick

The most used local stone in medieval churches is *Clunch* (Fig. 4a), the stonemason's name for harder units in the Upper Cretaceous Chalk Group. This group comprises fine-grained, mostly mud-grade limestones, increasingly containing terrigenous clay towards the base. Stratigraphically,

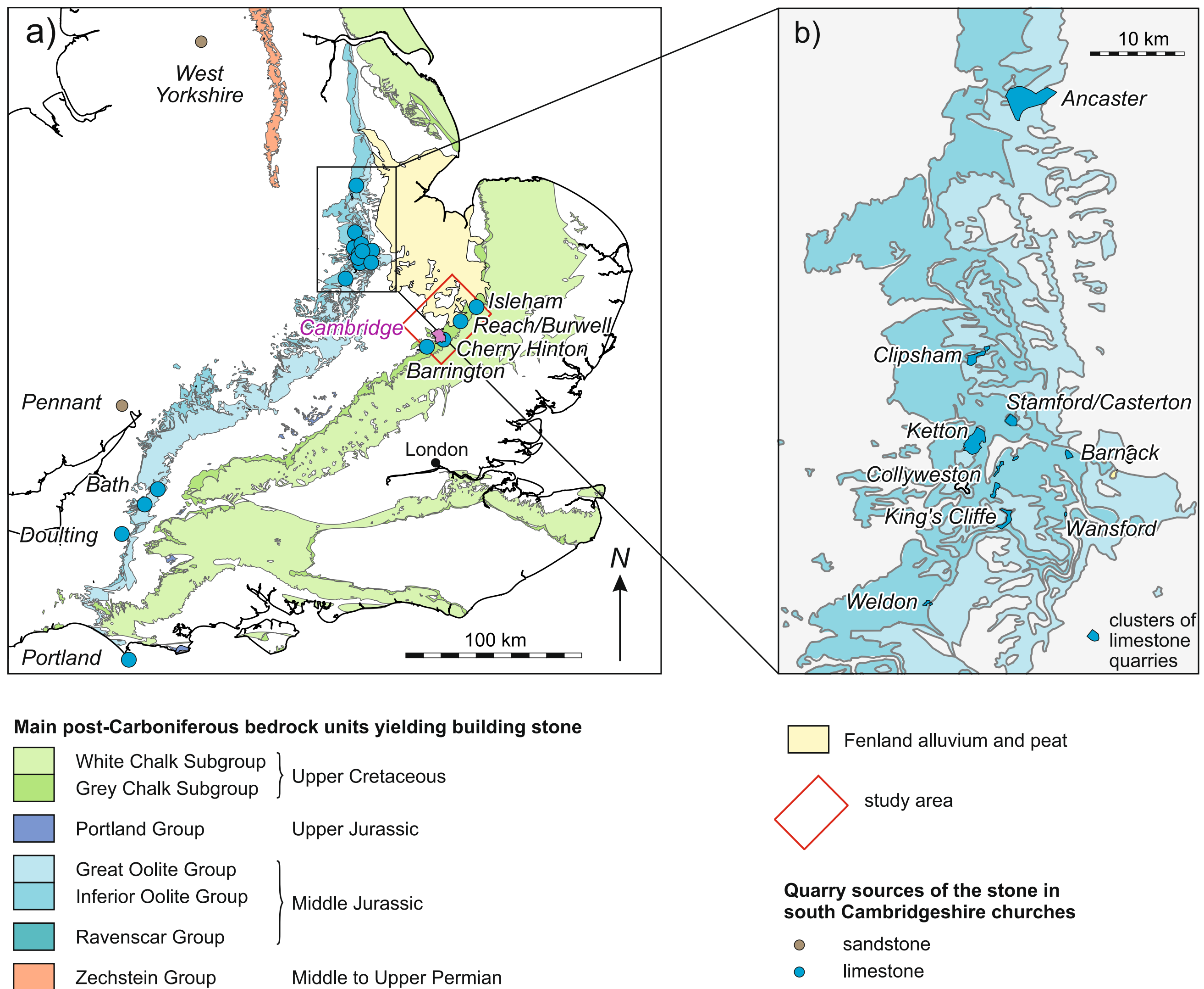


Fig. 1 **a**) Locations of main British quarries that have supplied building stone to south Cambridgeshire, on a map showing the Permian, Jurassic and Cretaceous stone belts. The study area and the low-lying Fens are shown. **b**) Inset enlarges the area of the Lincolnshire Limestone quarries. © Crown copyright and database rights 2023 Ordnance Survey (100,025,252); Geological Map Data BGS © UKRI 2023

Clunch is most likely to come from the Totternhoe Stone Member within the Grey Chalk Subgroup and less likely from the Melbourn Rock Member at the top of the subgroup (Fig. 2a, d). Geographically, most Clunch came from around Barrington, in the southwest of the study area, from (Cherry) Hinton near Cambridge, and from Reach, Burwell or Isleham towards the northeast (Fig. 2a).

Less commonly used in medieval churches are two local iron-rich stones. *Ely Sandstone* (Historic England 2023b) is a well-cemented variant within the Woburn Sands Formation (Fig. 2a, d). It is yellow to brown, medium to coarse-grained sandstone (Fig. 4b), commonly with dispersed sub-rounded granules or pebbles. The sand-sized grains are rounded to sub-angular and set in a cement mostly of calcite. By contrast, the '*Cottenham Sandstone*' (Historic England 2023b) is a *Ferricrete*, a deep brown conglomerate, pebbly sandstone or siltstone formed by ferruginous cementation of Quaternary river gravels (Fig. 4e). Many of the larger clasts are more angular than the Ely Sandstone, and of grey or brown-stained flint and other fine-grained lithologies. The distinction between these two ferruginous stones is detailed by Woodcock (2025).

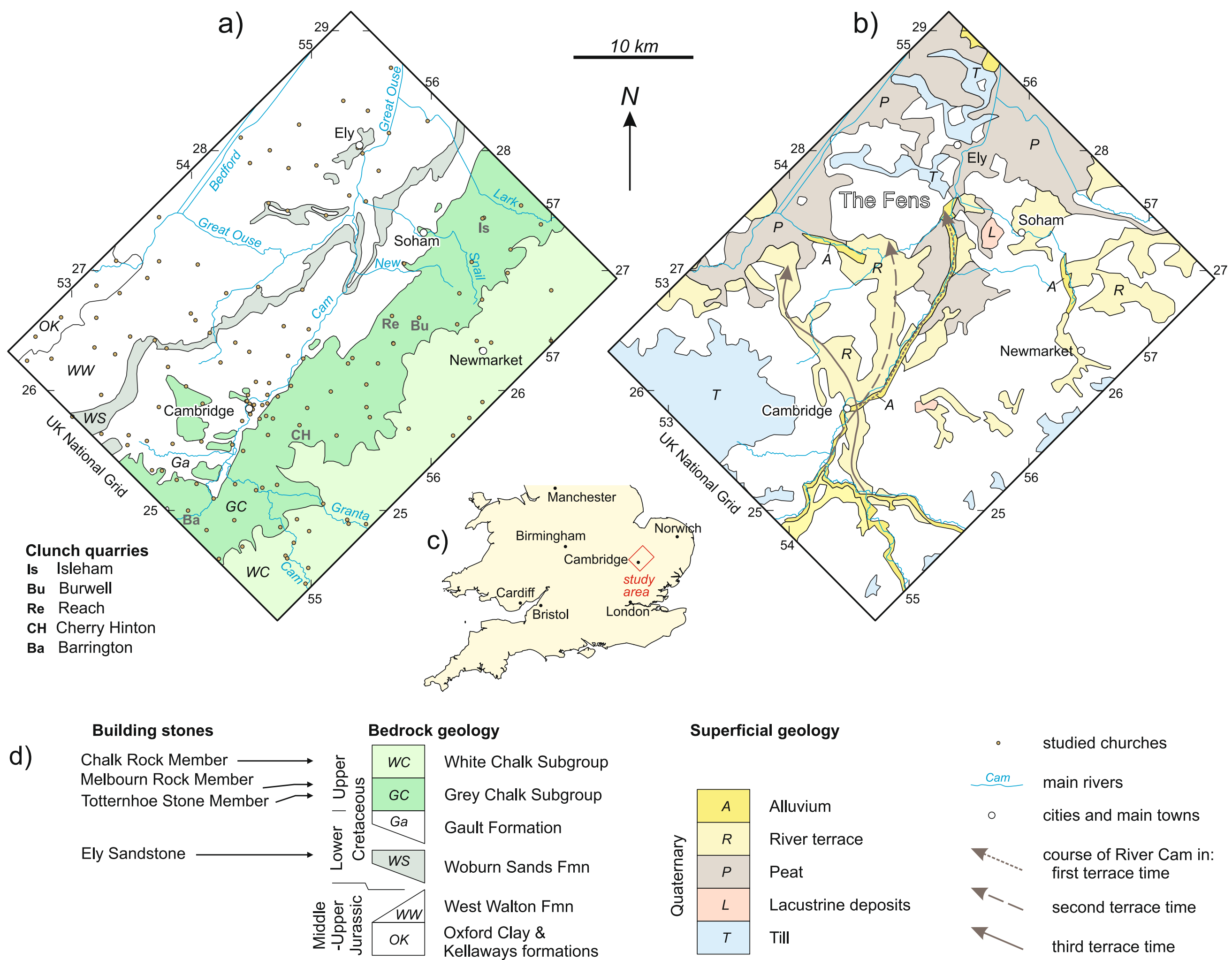


Fig. 2 **a**, **b**) Maps of the study area, with its location in southern Britain shown in Fig. 2c. Figure 2a shows bedrock units, main rivers and locations of the studied churches. Figure 2b shows superficial units and the former courses of the River Cam. **d**) Key to maps **a**) and **b**), showing also the stratigraphic position of the main building stones. © Crown copyright and database rights 2023 Ordnance Survey (100,025,252); Geological Map Data BGS © UKRI 2023

More common even than Clunch amongst locally sourced medieval building materials are *Fieldstone* (Fig. 4c) including *Field Flint* (Fig. 4d). These materials comprise subrounded clasts ranging in size from very coarse pebbles (32–64 mm) to fine cobbles (64–256 mm). The non-flint clasts are predominantly brown-stained quartzites, but various other lithologies occur that are exotic to south Cambridgeshire. Many flint clasts tend to be abraded and naturally fractured, suggesting that they were transported in the same way as the other Fieldstone clasts and were derived from weathering of the underlying Quaternary till or postglacial river gravels. The Fieldstone and Field Flint were harvested locally, mainly as a by-product of ploughing arable land.

Brick is a locally sourced walling material used mainly in post-medieval repairs or extensions. The common pale yellow or pink bricks (Fig. 4g) derive from the Lower Cretaceous *Gault* Formation (Fig. 3), particularly from brick pits around Cambridge and Burwell (Fig. 1). *Red bricks* (Fig. 4f) derive from more iron-rich, less calcareous clays, either from the Upper Jurassic Kimmeridge Clay Formation at Ely (Fig. 3) or from Quaternary brick clays local to the church being supplied.

Commonly used Stones from Distant Sources

The most used medieval stone from outside the study area was the Middle Jurassic limestone from Barnack (Fig. 5a). This was quarried from the Lincolnshire Limestone Formation (Inferior Oolite Group) just east of Stamford, 60 kms northwest of Cambridge (Fig. 1b, 3). *Barnack Stone* is a variably shelly, ooidal-peloidal limestone with a crystalline

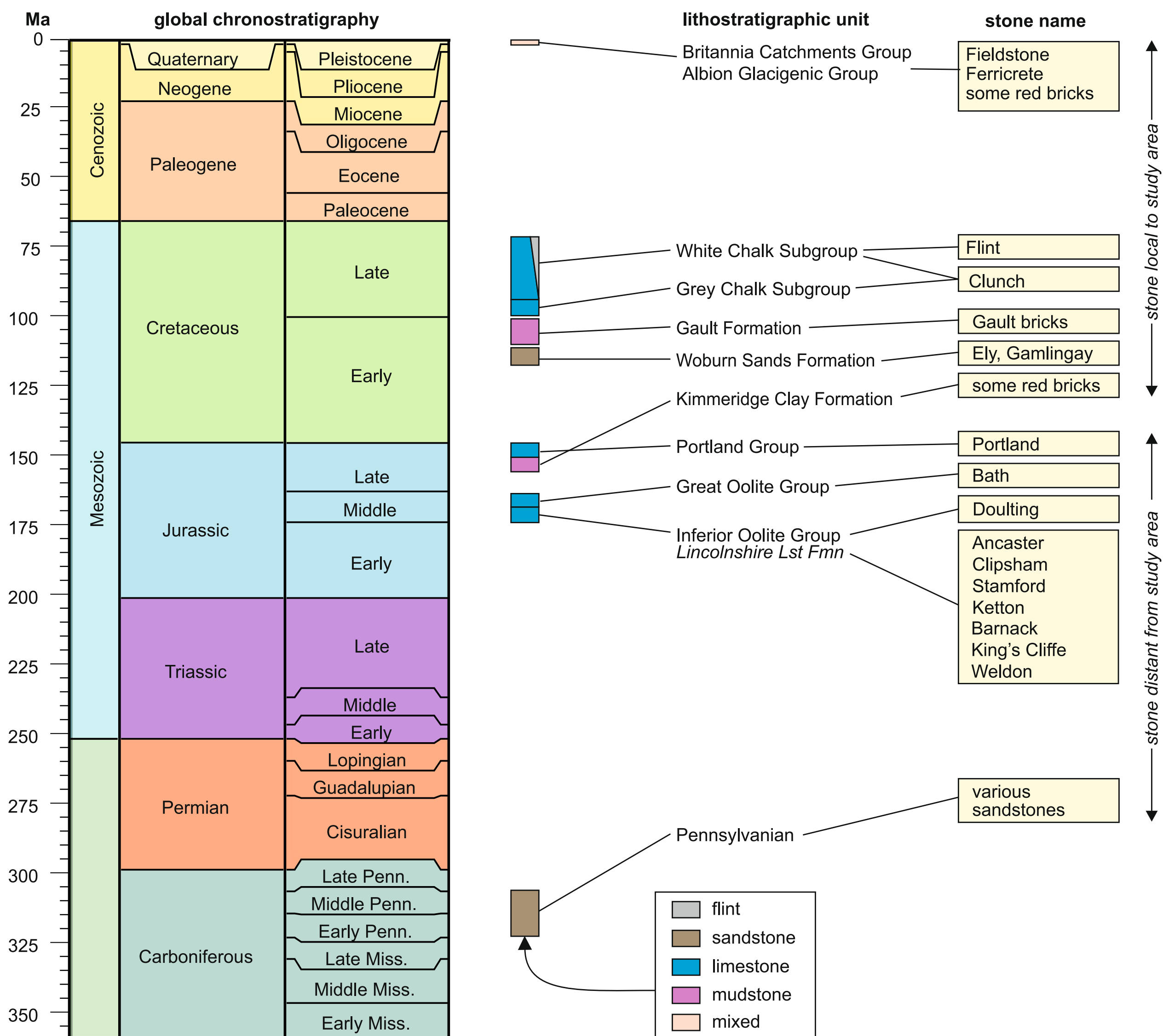


Fig. 3 Stratigraphic distribution of British building stone used in the study area. Locations of quarries shown on Fig. 1

calcite cement. The bedding-parallel shells weather more slowly than other components, standing proud of the etched surface (Fig. 5a). A richly shelly variant – the so-called Barnack Rag – is most common, with the shell-poor variant used in dressings that require detailed carving, particularly in window mullions and tracery.

Ragstone and *Blockstone* are shelly, peloidal, often micritic limestones in less equant or more equant pieces respectively (Figs. 5b, d). Used in rubble walls, Ragstone and Blockstone are of uncertain provenance, but may be from horizons of lower quality stone from the Lower Lincolnshire Limestone in the Barnack quarries themselves. Ragstone was only used in medieval time, but Blockstone continued to be used in post-medieval time.

After good-quality Barnack Stone ran out around in the mid-fifteenth century, the first replacement stone for dressings was *Weldon Stone* – at the southwestern limit of the Lincolnshire Limestone belt. The Weldon shelly ooidal limestone is distinctive in having voids up to 10 mm wide where gastropods have been dissolved out or where ooids never completely filled the space within or below bivalves (Fig. 5c).

The range of quarry sources in the Lincolnshire Limestone Formation increased for post-medieval repair and extension projects. *Ketton Stone* (Fig. 5e), from six kilometres west of Stamford (Fig. 1b), is a pure ooidal limestone with patchy calcite cement. East of Ketton, fine shell material dilutes the ooid content slightly (Fig. 5g), giving the *Stamford/Casterton Stone* (Fig. 1b). In the northern part of the Lincolnshire Limestone outcrop are the *Ancaster Stone* quarries (Fig. 1b) yield shelly ooidal limestones often with

Fig. 4 Locally sourced building stones (*italicised*) used in the study area: **a**) *Clunch* block rubble, Bottisham Holy Trinity, C13 west porch; **b**) *Ely Sandstone*, Ely St Mary, early C13 north aisle; **c**) *Fieldstone* rubble, Stourbridge St Mary Magdalene, later C12 nave north; **d**) *Field Flint* rubble, Horningsea St Peter, early C14 north aisle, part rebuilt 1865–7; **e**) *Ferricrete* rubble, Rampton All Saints, C12 nave north; **f**) Red brick walling, Witcham St Martin, c1691 rebuilt south aisle; **g**) Gault brick, Worlington All Saints, C18 rebuilt south porch

Fig. 5 Imported stones (*italicised*) commonly used in the study area: **a**) *Barnack* ashlar, Stourbridge St Mary Magdalene, later C12 chancel south; **b**) *Ragstone* rubble, Swaffham Prior St Mary, C15 north aisle; **c**) Weldon ashlar, Cambridge St Mary the Great, 1491–1550 tower west; **d**) *Blockstone* (oolite and Clunch) rubble, Willingham St Mary, early C14 south aisle; **e**) *Ketton*, Trumpington St Mary & St Nicholas, chancel east, 1912 buttress repair; **f**) *Ancaster*, Boxworth St Peter, 1868–69 tower west window; **g**) *Stamford/Casterton*, Stretham St James, C20 repair to early C14 tower south; **h**) *Bath*, Horningsea St Peter, north aisle, 1865–67 replaced window

Fig. 6 Imported stones (*itlacised*) infrequently used in the study area: **a**) *?King's Cliffe*, Fenstanton St Peter & St Paul, 1345–52 chancel east window; **b**) *Clipsham*, Great Abington St Mary, north porch, 2016–17 window; **c**) *Doulting*, Stretham St James, south aisle, 1875–76 west window; **d**) Carboniferous sandstone maybe *Pennant*, Haddenham Holy Trinity, tower north, 1871–77 buttress repair

a characteristic centimetric 'streaky bacon' striping cause by variable calcite cementation (Fig. 5f).

Bath Stone is derived from the Great Oolite Group, nearly 200 kms away in southwest England (Figs. 1, 3). These shelly ooidal limestones (Fig. 5h) are recognisable first because their ooids have often been dissolved out to leave voids in a prominent calcite cement and second because sporadic thin calcite veins cut bedding at a high angle.

Infrequently used Stones from Distant Sources

A few less commonly used stones are illustrated in Fig. 6.

King's Cliffe Stone is a shelly ooidal limestone from the southern Lincolnshire Limestone belt (Fig. 1b) occasionally used in medieval dressings. It has a distinctive dark to light brown enhancement of the bedding fabric by variable calcite cementation (Fig. 6a).

Clipsham Stone, from 10 kms north of Stamford, is a shelly ooidal limestone that was used sparingly in Victorian restorations. Its character has varied significantly through time, and more shelly variants may prove to rival Barnack in their appearance and longevity.

Doulting Stone comes from close to the Bath quarries in southwest England (Fig. 1a), but from the Inferior Oolite Group rather that the Great Oolite (Fig. 3). It is a bioclastic limestone (Fig. 6c), but notable for its echinoderm debris rather that the bivalve-dominated content of most Middle Jurassic limestones.

Finally, there is a small volume of fine sandstones, apparently Carboniferous, deployed decoratively in dressings (Fig. 6d) and randomly in rubble walls. The sources of these sandstones are uncertain, although a laminated greenish-brown variant may be *Pennant Stone* from South Wales.

Quantitative Survey Methodology

The 124 surveyed churches all originated as pre-Reformation parish churches or monastic chapels. A cut-off date of 1550 has been selected, a decade or so after Henry VIII disbanded the monasteries, convents and friaries of England, Wales and Ireland between 1536 and 1541, and separated the Church in England from papal authority. Rapid decrease in construction and renovation of churches happened over the following decade. The study therefore excludes all Anglican churches originating in the Victorian Gothic revival, all twentieth century churches and all nonconformist places of worship. For context, out of the 306 churches and chapels in historic Cambridgeshire, 57% are medieval foundations, 8% are from the later 16th to eighteenth centuries, 18% are nineteenth century, and 17% are twentieth century.

The study includes some medieval churches that were mostly rebuilt during the Victorian 'restorations', but that

incorporate components such as windows and doors from their predecessors. These five rebuilt churches are Fulbourn St Vigor, Papworth Everard St Peter, Papworth St John the Baptist, Stuntney Holy Cross and Toft St Andrew. The other 119 churches include at least one surviving medieval part of the church – for instance the tower, nave or chancel – and most churches include all of these.

Roofs on churches and the paving within and around them were excluded from the survey because successive re-laying makes these elements difficult to date. Constructional stone used internally was excluded, because render, lime wash or paint often make identification difficult. Excluded also is stone in internal and external monuments.

Each church was recorded using a methodology analogous to that of Woodcock and Furness (2021) for Cambridge buildings. Each church, located by a British National Grid reference, was first subdivided into its main architectural parts: tower, nave, north and south aisles and chancel, with the possible additions of clerestories, porches, transepts, chapels and vestry. For each part, a separate record was made for the walling, the openings and the other dressings. Each record contained:

1. Two levels of locality information (for instance church name, chancel).
2. Detail of the stone position (for instance, east window) within that part.
3. Stone identification to an individual quarry or cluster of quarries, confirmed by documentary evidence if possible.
4. The year range of the building project, mainly taken from the reports of the Royal Commission for Historical Monuments (Royal Commission on Historical Monuments, England 1960, 1968, 1972) from the Pevsner 'Buildings of England' guides (Bradley and Pevsner 2014; O'Brien, Charles and Pevsner 2014; Bettley and Pevsner 2015) or from the various Victoria County Histories (e.g. Roach 1959).
5. The architect for the building or restoration project, if known.
6. A rough estimate of the volume of stone used in each part of the church, obtained by multiplying a component factor (1 for stone used as dressings and 2 for walling) by an extent factor (typically 1, but set to 0.5 for a limited repair).

This methodology typically produced between 10 and 30 records for each church, each record representing an individually dated construction, repair or restoration project. Each record was entered as a line on an Excel spreadsheet. The total number of records in the database is 2203, an average of about 18 records per church.

Two warnings need to be recorded concerning the accuracy of the stone database. Firstly, not all stones can be unambiguously identified, and misidentifications will inevitably occur. Secondly, the assigned age ranges may sometimes be inaccurate; primary sources such as parish records may not be fully reflected in the secondary sources consulted and there is the difficulty in dating masonry from the style of the openings it contains.

With these warnings in mind, the main database has been filtered, sorted and plotted in Excel to produce a range of charts. For charts that plot volumes of a particular stone across the whole study area, the raw records were filtered for that stone, entered on a separate spreadsheet, then summed. For charts that display a volume of a specific stone type for each church, that volume is an average of the values for the four main parts of the church: tower, north nave or aisle, chancel, and south nave or aisle. This average volume is a valuable parameter as it allows maps and charts to be created showing the frequency of a specific stone across the study area (Figs. 11, 12). However, the average volume parameter assumes that the volume of stone is similar in each of the four parts of the church, which is in turn dependent on their relative dimensions. Such accurate measurements are beyond the scope of this study.

Of the 2203 total records, 549 were for rubble walls. The composition of these walls was visually assessed in the field in terms of the percentage area of wall occupied by one of 12 different lithologies. As with stone for dressing and ashlar walls, these data could either be summed across the whole area or used to derive an average rubble composition for each church.

The Excel workbook, containing the raw data and the sheets for each stone, has been deposited with the UK National Geoscience Data Centre. (Woodcock 2024).

Relative Total Volumes of Stone Types in the Study Area

Medieval Stone Volumes

The relative volumes of different stone types in the study area are shown by pie charts (Fig. 7), with walls assessed separately to dressings, and pre- and post-1550 stone assessed separately.

The most striking result is that most medieval dressings were of Clunch and Barnack (Fig. 7a). Clunch (37% of pre-1550 dressing stone) would have been favoured because it was locally quarried, so had low transport costs. However, Clunch is not durable in exposed external locations over decades and centuries. By contrast, imported Barnack (62% of dressings) had a reputation for durability dating back at least to late Anglo-Saxon time (e.g. Jope 1964; Everson and

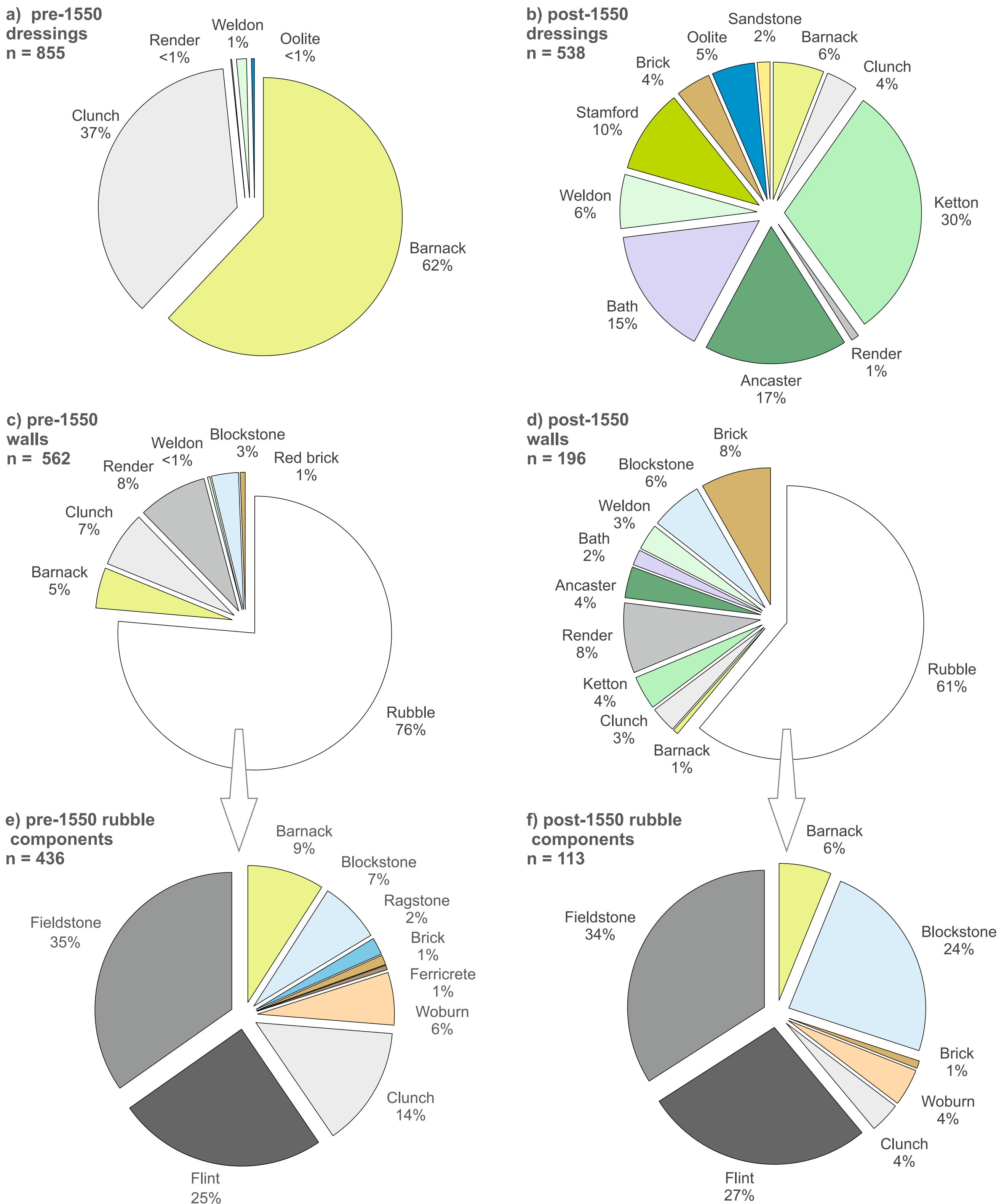


Fig. 7 Pie charts with relative volumes of stone types used in (**a**, **b**) dressings and (**c**, **d**) walls in churches in the study area. Rubble wall components are plotted separately (**e**, **f**). In each case, volumes before 1550 (**a**, **c**, **e**) and after 1550 (**b**, **d**, **f**) are distinguished. Local stone types are coloured in shades of grey and brown, and imported types in more colourful tones

Stocker 2019). It would be chosen for exposed locations if its higher quarry-gate and transport costs could be afforded.

A qualitative assessment suggests that use of Barnack in openings prioritised sills and hood moulds, then mullions and lower jambs, then upper jambs and arches, and finally tracery. Other dressings used Barnack first in string courses, then buttress setoffs, plinth strings, buttress quoins and other quoins. This assessment will be tested more quantitatively in a later study.

Medieval walls (Fig. 7c) are predominantly (76%) rubble with a further 8% rendered, presumably concealing rubble. The remaining ashlar walls are mostly of either local Clunch (7%) or imported Barnack (5%). The rubble walls (Fig. 7e) mainly comprise local Field Flint (25% of rubble) or other local Fieldstone (35%), but with local Clunch (14%) and imported Barnack (9%) in blocks that are too irregular, or of too low quality, to be used for dressings or ashlar. There are sporadic carved blocks of Barnack stone reused as 'spolia' presumably from an earlier, Anglo-Saxon or Norman, church on the same site. Medieval rubble also contains Blockstone or Ragstone from uncertain sources, but some probably from the Lower Lincolnshire Limestone in the Barnack area. Local ferruginous stones form a minor component of rubble walls, Ely Sandstone (6%) in the north of the area and Ferricrete (1%) in the west central area (Woodcock 2025).

Summing the stone use in both walls and dressings (Fig. 8a) shows that locally sourced materials – Clunch, Fieldstone, Flint, Woburn and brick – account for about 53% of pre-1550 external stonework. Nevertheless, an impressive 42% of stone was imported from the Lincolnshire Limestone belt, mostly Barnack but including some Weldon and non-specific Blockstone and Ragstone.

Post-Medieval Stone Volumes

There was very little external repair or extension of church buildings from 1550 until about 1840 (Sect. 6 below). It is striking (Fig. 7b) that Victorian replacement of dressings used a much greater range of stone than the medieval mix of Barnack and Clunch. Clunch, brick, render and reused Barnack together make up only 15% from local sources. The remaining 85% of stone for dressings had to be imported, a venture made less costly by the rapid development first of the canal network and then the railway system. Most imports came from the Lincolnshire Limestone belt, but now from a range of quarries rather than just from the Barnack area: Ketton, Ancaster, Stamford/Casterton, Weldon and unidentified oolite. A surprisingly large volume of limestone (15%) came from the Bath quarries in southwest England, and a small volume (2%) of sandstone from the Carboniferous, probably of Yorkshire or the Forest of Dean.

Victorian walling (Fig. 7d), both new-build and repair, presents less of a contrast with medieval walling than do

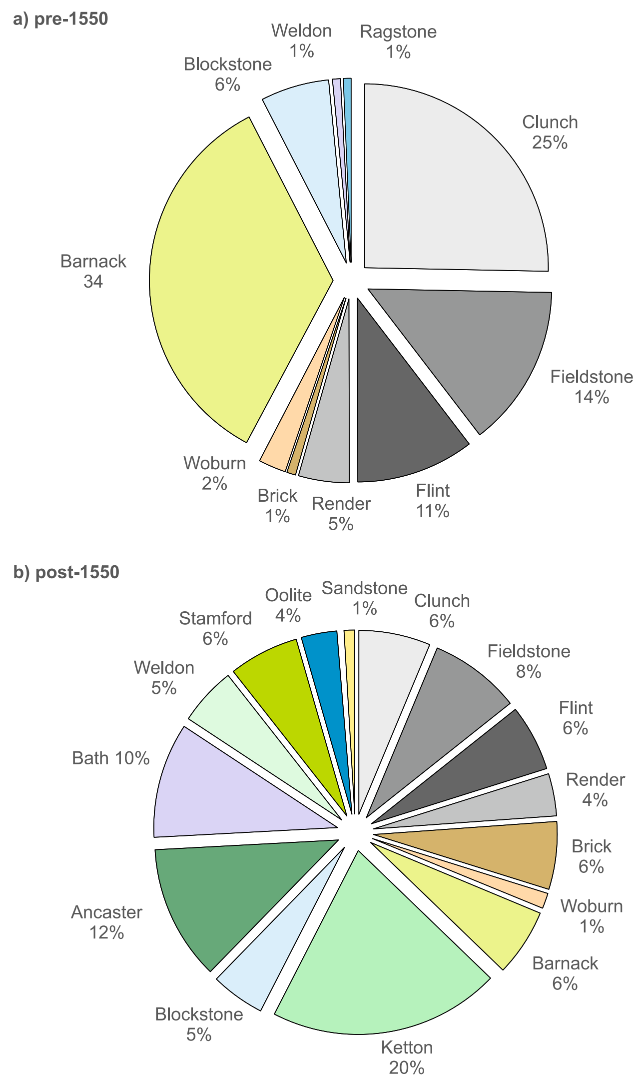


Fig. 8 Pie charts with relative volumes of stone types summing the contributions from dressings, ashlar walls and rubble walls. Chart 8**a**) is for pre-1550 projects and chart 8**b**) for post-1550 projects. Local stone types are coloured in shades of grey and brown, and imported types in more colourful tones. Stones with a volume of less than 1% are omitted

dressings. Rubble still predominates – 61% of Victorian walling rather than 76% before 1550 – with a significant percentage (8%) of walls again rendered over probable rubble. Local brick, either reds or yellow Gaults, makes up a significant 8%. Ashlar walls (23%) have a similar range of stone to dressings, mostly Ketton, Ancaster, Weldon and non-specific Blockstone with small volumes used of Clunch, recycled Barnack and distant Bath.

Victorian rubble walls contain a very similar mix of stone to their medieval counterparts (compare Fig. 7f and Fig. 7e). Fieldstone (34% of rubble) and Flint (27%) are present in very similar proportions to medieval rubble, as are recycled Barnack (6%), Woburn (4%) and brick (1%). By contrast,

Clunch (4%) is less common than in medieval rubble, the deficit being made up of Blockstone (24%), mostly of unidentified limestone. The remarkable similarity of medieval and Victorian rubble strongly suggests that most Victorian walls were rebuilding projects using materials recycled from the precursor medieval walls. Even where Victorian builders added a new rubble porch or vestry, they clearly tried to match up materials with the remainder of the church.

Summing the Victorian stone use in both walls and dressings (Fig. 8b) shows that locally sourced materials only account for about 37% of external stonework, compared with 58% in medieval projects. Equally important local contributors were still Clunch, Fieldstone, Flint, recycled Barnack and brick. The remaining 63% of stone was mostly imported from the Lincolnshire Limestone belt, but from at least four quarry areas rather than just Barnack as in medieval projects. A full 10% of stone came from the Bath quarries of southwest England.

Volume of Total Stone use Through Time

Data Display

Because each of the 2230 records of building projects has an estimated date range, it is possible to sum volumes of all stone (this section) or individual stone types (next section) for any chosen time interval.

The data are plotted as histograms of the volume of stone used in each decade from the year 1000 to the present day (Fig. 9a), using the semi-quantitative volume parameter explained in the methodology section. Where a building project spanned several decades, its volume is apportioned equally across all the decades involved. Where a project is imprecisely dated, its volume is apportioned across all decades of the possible age range. Volumes of all project contributions in each decade are summed to get the plotted volume (Fig. 9a).

An important caveat to interpreting the data patterns is that they record only those building projects that have survived later replacement. For instance, there are some

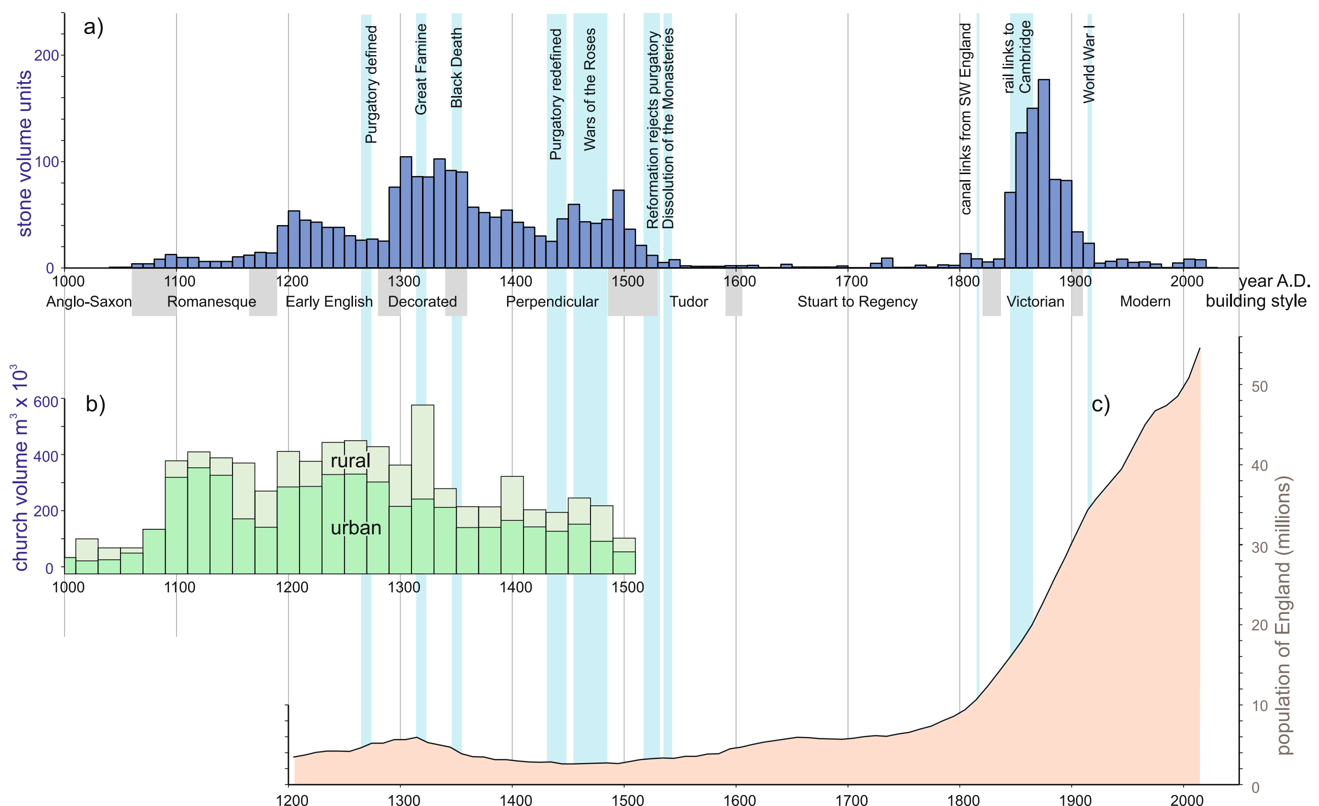


Fig. 9 **a**) Total volume of stone preserved in each decade from 1000–2020 in medieval churches in the study area, with architectural styles also shown. (**b**) Volume of urban and rural churches built in Great Britain from 1000 to 1500 (Buringh et al. 2020, Fig. A5). (**c**) Population of England from 1200 to present. Annual estimates from 1200–1860 from Clark (2010). Decadal census data after 1861 from https://www.visionofbritain.org.uk/unit/10061325/cube/TOT_POP with decadal population linearly interpolated between census dates. Key historical events also marked across each plot

essentially Gothic, post-1190, churches in the study that have documentary evidence of a Romanesque precursor or have included stone pieces, *spolia*, with Romanesque decoration. Most parts of such churches would be assigned the date of the Gothic rebuilding and only minor components – for instance, a retained Romanesque doorway or a reset window – might be recorded as pre-1190.

With that proviso, the first check to be made on the histogram is whether there is obvious 'age heaping' (e.g. Heitjan and Rubin 1990). Age heaping is common in 'coarse' datasets where some or all ages are rounded to approximate age ranges. Rounding generates spurious peaks at the rounding values. Some heaping might be expected in survey age plots, but from several types of rounding; to fractions of a century – such as 'early fourteenth century' so 1300–1350 – or to the boundaries of medieval architectural styles – 1190, 1290, 1350 and 1530. However, the method used here of dividing volume estimates across the whole of their possible age range should decrease or remove heaping. Consequently, although the histogram (Fig. 9a) shows possible heaping at 1200 and 1300 rather than 1190 and 1290, later ages show no defined heaps. Accordingly no correction of the data has been attempted (Heitjan and Rubin 1990). However, the temptation must be resisted to over-interpret single decadal peaks rather than using the patterns over several decades.

A search of the published literature has failed to find a record of church building in England with a better sample size and age resolution than the south Cambridgeshire study. The next best record (Fig. 9b) is from the study by Buringh et al. (2020) of large urban and rural churches across Europe. Because of its breadth, this study was necessarily more generalised than the present survey. It recorded just the major building phases for each church – an average of 2.6 phases per church – with volumes estimated from measured floor areas of the relevant component. Dates of building phases were given in 20-year bins rather than decadal bins. The British sample includes 176 urban churches in 135 towns and cities, and rural churches in two sample areas, including about 25 large churches in Cambridgeshire, south Lincolnshire, and parts of bordering counties to the west.

A third relevant curve (Fig. 9c) is of the English population from 1200 to 1860 as estimated by Clark (2010) and as measured from 1861 by the decadal UK census data.

Medieval Patterns and Causes

The general shapes of the pre-1550 volume curves (Figs. 9a, b) are similar; an increase in church building and rebuilding activity through the 11th to thirteenth centuries peaking in the earlier fourteenth century, then decreasing intermittently to very low volumes after the mid-sixteenth century. Some suggested influences on this pattern are:

1. The post-Conquest surge in building is partly due to the establishment of the parish system through the eleventh and twelfth centuries (Rodwell 2012 p. 72; Orme 2021 p. 75). Anglo-Saxon single-celled churches were replaced at least by two-celled churches with a rectangular nave, maybe with narrow aisles, and a short chancel. Evidence may only survive as excavated foundations or as *spolia* in the new walling.
2. Increased activity in the late twelfth and thirteenth centuries is seen in the Cambridgeshire data (Fig. 9a) and the comparative dataset (Fig. 9b). It has been linked to the enlargement of chancels, due to evolving liturgical ritual requiring more clergy and furnishings, and to the widening of aisles and addition of porches as population grew steadily (Fig. 9c) (Rodwell 2012 p. 72).
3. An important stimulus to the charitable funding of church renovations was probably the statement of Catholic teaching on Purgatory at the 2nd Council of Lyon in 1274: *"Moreover, if anyone without repentance dies in mortal sin, without a doubt he is tortured forever by the flames of eternal hell. But the souls of children after the cleansing of baptism, and of adults also who depart in charity and who are bound neither by sin nor unto any satisfaction for sin itself, at once pass quickly to their eternal fatherland"* (Denzinger 2012 EN 839). Contemporary handbooks of penance decreed that gifts towards the building of churches would reduce the time spent in purgatory (McNeill and Gamer 1990; Brown 1995 p.8).
4. A decrease in church building and repair is seen in both the datasets (Figs. 9a, b) in the later fourteenth century. This decrease was likely due to the combined effects of the Great Famine (1315) and the Black Death (1349–50 and 1361–2 in England) (e.g. Brown 1995). Estimates of the death rate from the plague alone vary from 45% to 62.5% (Benedictow 2004), reason enough for the late fourteenth century building decline.
5. An unexplained spike in the national church building sample around 1400 (Fig. 9b) is subdued in the Cambridgeshire data (Fig. 9a) and decrease in activity in both areas continued into the mid-fifteenth century.
6. The upturn in building activity in Cambridgeshire and nationally in the mid-fifteenth century (Figs. 9a, b) cannot result from population increase, which remained negligible until the end of the century (Fig. 9d). It is more likely due to the restatement of the doctrine of Purgatory by the Council of Florence (1431–49) with a resultant increase in indulgences – remissions of penance – for parish good works (Brown 1995 p. 8).
7. The higher levels of building activity continued through the later fifteenth century, The dip in activity in Cambridgeshire during the Wars of the Roses might be ignored, if it was not also a feature of church, university and college building in Cambridge city (Woodcock and

Furness 2021 Fig. 12). The dip may be due to diversion of both materials and labour for military purposes.

8. There is a steep decline in building activity in the early half of the sixteenth century. This decline would have been fuelled by the Protestant Reformation – gaining influence from about 1517 and rejecting the doctrine of Purgatory – and the Act of Supremacy (1534), which detached Henry VIII's Church of England from papal authority. The Dissolution of the Monasteries (1536–41) marked the end of most parish church building and repair for about 250 years. However, why the decline in Cambridgeshire church building started before all these movements, at the turn of the sixteenth century (Fig. 9a), is unexplained.

Post-Medieval Patterns and Causes

The pattern of south Cambridgeshire church building and repair after 1550 (Fig. 9a) must be interpreted with the proviso that it only contains data from churches with medieval origins.

1. The dearth of building projects between 1550 and 1800 is striking, and most of this activity was minor repairs. The only substantial projects were heightened towers at Holywell, Conington, Cottenham and Cambridge St Mary the Great, clerestories at Holywell and Babraham, the nave at Conington, and chancels at Boxworth and Cambridge St Clement. The building gap also applies to non-conformist chapels in the study area, with very few surviving from before 1830 (Bradley and Pevsner 2014 p. 403).
2. The rapid population increase beginning from the later eighteenth century (Fig. 9d) did not feed through into church enlargement and building until after the accession of Queen Victoria in 1837. However, rather than a change of monarch, the trigger for church building and restoration came from two linked movements: a) the revisions of theological and liturgical practice within the Anglican Church initiated in 1833 by John Henry Newman and the Oxford Movement, and b) the influence of the Cambridge Camden Society, founded in 1839, on church architecture. The Cambridge group, renamed the Ecclesiological Society in 1845, campaigned to return parish churches to what the Society believed was their original medieval splendour. Their pamphlets (Neale 1841, 1842) and their journal "The Ecclesiologist" were nationally influential, and sparked the 'Restoration' of many English parish churches and the construction of many new Gothic Revival churches. Locally, the Cambridge architects W.M. Fawcett and R.R. Rowe were prolific restorers, but many other London architects were active in Cambridgeshire.
3. The volume histogram for south Cambridgeshire (Fig. 9a) shows a rapid increase in alterations to medieval churches from 1840 to a peak in the 1870s. The establishment first of canal links to Cambridge from southwest England (1815) then of national railway links (from 1845) greatly increased the range of affordable stone that Cambridge builders could source.
4. The equally rapid decline in building activity in the 1880s and '90 s coincides with a fall from fashion of Gothic architecture and of the Restoration movement. After World War I, increasingly expensive stone was only used for necessary repairs to medieval churches.

Volume of Individual Stone Types Through Time

Data Display

Histograms for each individual stone have been produced (Fig. 10) using the same methodology as for the aggregated histogram (Fig. 9a). The plots all have the same vertical volume scale. They are arranged in order of the earliest preserved use of the stone in the study area. The vertical spacing of the histograms is for graphical convenience only. The plots are coloured according to the stratigraphic position of their host unit.

The age distributions are clearly of two types: in the first column (Fig. 10), the medieval stones from Barnack to red brick that began to be used by 1400 and, in the second column, those from Ketton to Portland that came into use after 1700.

Temporal Pattern of Medieval Stone Use

The first-used stone types preserved in the study area are Fieldstone and Flint for rubble walling, and Barnack and Clunch mostly for dressings. All these types appeared by the end of the eleventh century (Fig. 10) and have a similar late medieval pattern of use, peaking in the fourteenth century and declining to zero or negligible volumes by 1550. They all show a second peak in the nineteenth century due to re-use of medieval stone during restoration or, for Clunch, replacement with newly quarried stone.

It is notable that, as in the study of Cambridge buildings (Woodcock and Furness 2021), Barnack freestone for dressings was being sourced for Cambridgeshire churches right through the fifteenth century (Fig. 10). This evidence suggests that the Barnack quarries had not been exhausted of this good stone in the mid-fourteenth century as deduced by Everson and Stocker (2019). Substantial use of Barnack

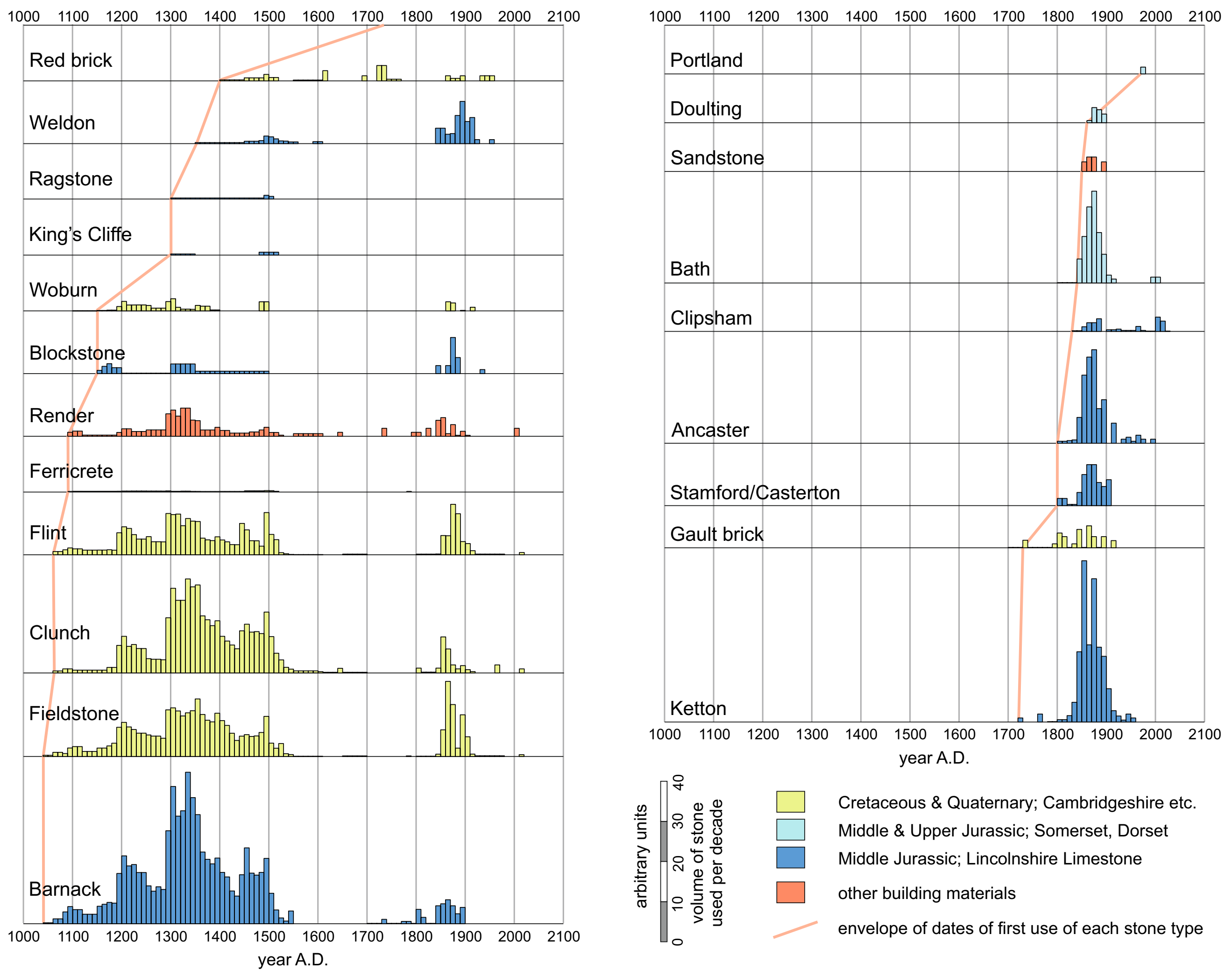
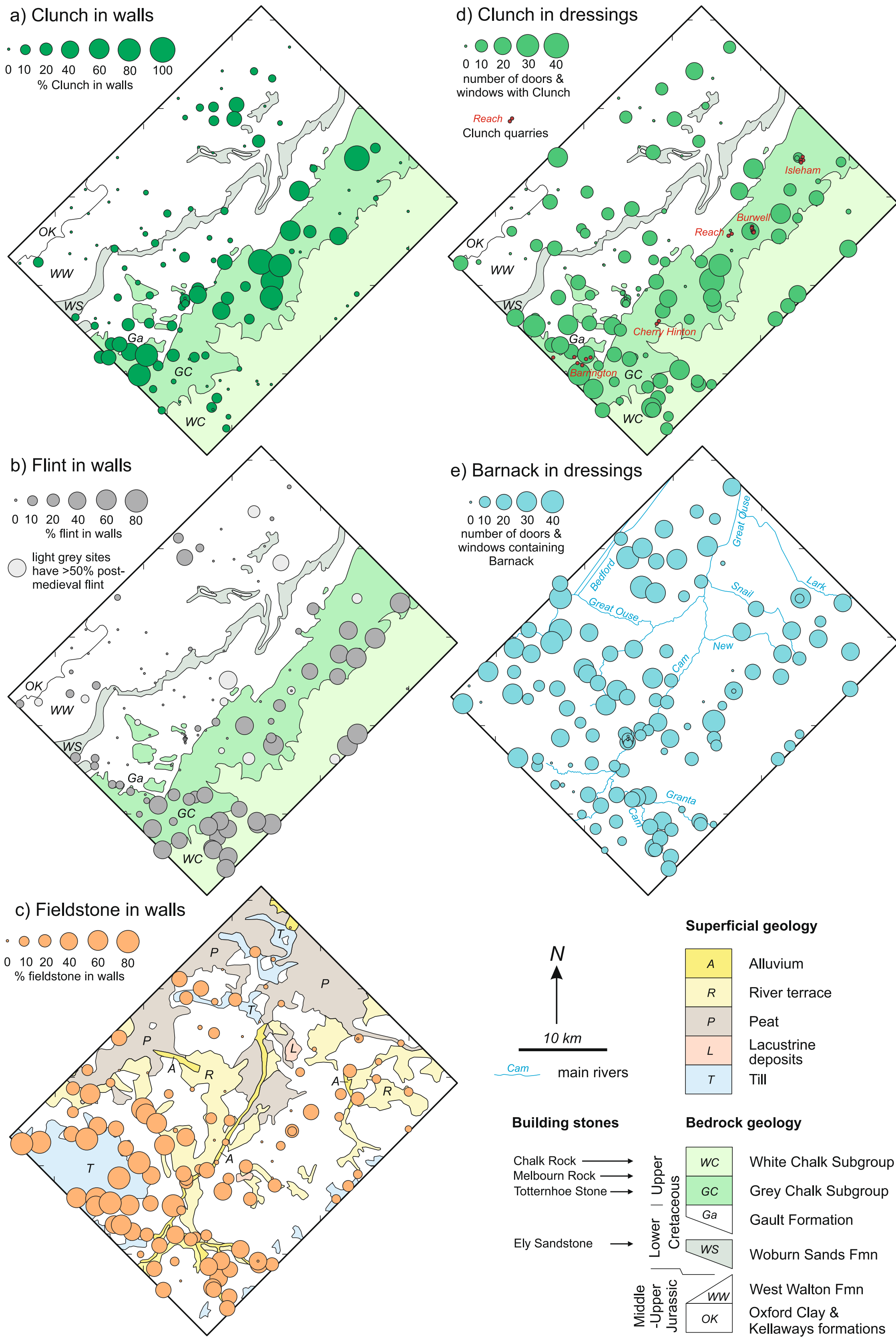


Fig. 10 Decadal volumes of individual stone and other walling types in medieval churches in the study area 1000–2020. Histograms are arranged in order of first use of that stone. All histograms are to the same scale in arbitrary volume units defined in the text. Vertical spacing of the histograms varies for graphical convenience only. Locations of relevant quarries shown on Fig. 1

stone in the later fourteenth century is recorded at Duxford St Peter, Hardwick St Mary, Witchford St Andrew, Yelling Holy Cross and Bluntisham St Mary, and less voluminous use in about 34 other churches. Substantial earlier fifteenth century use of Barnack stone is recorded at Great Shelford St Mary, Fen Drayton St Mary, Harston All Saints, Hilton St Mary, Impington St Andrew, and Landwade St Nicholas, with less voluminous use in about 38 other churches. Dressed blocks of this stone do not apparently show the chipped edges and corners characteristic of reused freestone. The first well-dated indications that Barnack freestone was running out are the uses of Weldon stone in the towers of Burwell St Mary (1450–77), Cambridge St Mary the Great (1491–1550) and Soham St Andrew (1496–1502), all of them wealthy churches that could have afforded Barnack if it was still available.

Nevertheless, Barnack stone projects are still recorded after the likely exhaustion of the quarries in the mid-fifteenth century (Fig. 10). Most of these records are of stone reused from a pre-existing part of the same church. This is explicitly recorded at Great Eversden St Mary (Royal Commission on Historical Monuments, England 1968 pp. 121–126), Kingston All Saints and St Andrew (Royal Commission on Historical Monuments, England 1968 pp. 152–160), Moulton St Peter (Historic England 1954), and Wilburton St Peter (Pugh 2002). Only in one project, the tower at Holywell St John the Baptist (1547–8), was stone reused from a recently dissolved Fenland abbey, here Ramsey Abbey (Royal Commission on Historical Monuments, England 1926 pp. 140–142). This lack of Barnack reuse from abbeys contrasts with the high rate in Cambridge college buildings; at least five projects between 1555 and 1606 (Woodcock and Furness 2021). It


a) Clunch in walls
0 10 20 40 60 80 100
% Clunch in walls
OK
WW
WS
Ga
GC
WC
d) Clunch in dressings
0 10 20 30 40
number of doors & windows with Clunch
Reach
Clunch quarries
Isleham
Burwell
Reach
Cherry Hinton
Barrington
b) Flint in walls
0 10 20 40 60 80
% flint in walls
light grey sites have >50% post-medieval flint
e) Barnack in dressings
0 10 20 30 40
number of doors & windows containing Barnack
Great Ouse
Bedford
Snail
Lark
New
Cam
Granta
c) Fieldstone in walls
0 10 20 40 60 80
% fieldstone in walls
P
T
A
R
L
N
10 km
Cam
main rivers
Superficial geology
Alluvium
River terrace
Peat
Lacustrine deposits
Till
Building stones
Bedrock geology
Chalk Rock
Melbourn Rock
Totternhoe Stone
Ely Sandstone
Upper
Lower
Cretaceous
Middle -Upper Jurassic
White Chalk Subgroup
Grey Chalk Subgroup
Gault Formation
Woburn Sands Fmn
West Walton Fmn
Oxford Clay & Kellaways formations

◂**Fig. 11** Spatial distribution of selected stones in the study area. Maps (**a**, **b**, **c**) show the percentage of **a**) Clunch, **b**) Flint and **c**) Fieldstone in walls, averaged across the whole church. Maps (**d**, **e**) show the number of doors and windows that contain components of **d**) Clunch and **e**) Barnack. Base maps show (**a**, **b**, **d**) bedrock geology, **f**) superficial deposits, and **e**) present river system

seems that the appetite for rebuilding churches had mostly been suppressed by the ongoing Reformation.

Another contrast with Cambridge buildings is that volumes of Fieldstone and Flint only show a gentle decline in abundance after 1350 (Fig. 10). These data therefore offer only qualified support for the hypothesis (Woodcock and Furness 2021) that the supply of Fieldstone strongly declined due to lowered agricultural activity after the Black Death (1348–49).

Four minor types of rubble walling stone appear in churches by 1300: the ferruginous lithologies of Ely Sandstone and Ferricrete, and the generic types of Blockstone and Ragstone. Render is recorded on rubble walls dated as early as 1100, but it is impossible to know how many times this covering has been removed and renewed, and whether it dates back to the construction of the wall itself. Red brick is used for repairs and small projects such as porches from the fifteenth century: e.g. Witcham St Martin, and Fordham St Peter & St Mary Magdalene. Two minor stone types – Weldon and King's Cliffe – supplemented Barnack and Clunch in dressings.

Temporal Pattern of Post-Medieval Stone Use

A number of 'medieval' stone types were also used during the nineteenth century wave of church 'restoration.' Barnack and Ely Sandstone were no longer available and the age distributions (Fig. 10) record their reuse in rebuilding projects. Fieldstone and Flint might also be reused but were commonly supplemented by inappropriate assemblages of cobbles from unknown sources. Weldon had a strong nineteenth century surge of popularity, and Clunch also remained available for minor repairs, and occasionally for ashlar rewalling such as at (Cherry) Hinton St Andrew.

New Lincolnshire Limestone types were popular in the nineteenth century. Most voluminous amongst these was the pure oolitic limestone from Ketton, five kilometres west of Stamford (Fig. 1b) together with the slightly more shelly variant from quarries between Stamford and Casterton. Ketton had become popular in the seventeenth century and, by the nineteenth century, was the most widely used stone in Cambridge colleges and the university. The Ketton and Stamford/Casterton quarries are close to the River Welland, but the mid-nineteenth century expansion of the railway system provided a cheaper and quicker mode of stone transport to south Cambridgeshire. The railways also made economic several Lincolnshire Limestone quarries more distant from rivers; a small volume of stone from Clipsham, 11 kms north of Stamford, and a much larger volume from Ancaster, 26 kms north again (Figs. 1b, 10).

The railways also brought oolitic limestone from the Bath quarries of southwest England (Fig. 1), used particularly for replacing window mouldings. Although Lincolnshire Limestones were equally suitable, vigorous advertising and price-cutting through the 1860s to 1880s (Hudson 1971 p. 58–9) made *Bath Stone* the popular choice. The small volume of *Doulting Stone* from the same region (Fig. 1) was probably used at Little Abington St Mary and Stretham St James only because it was the favourite of the restoration architect J. P. St Aubyn. The one example of *Portland Whitbed* from southern England was used as a colour match in the 1970s at Stapleford St Andrew to replace Clunch.

Spatial Distribution of Common Medieval Stone Types

Rationale for Investigating Spatial Patterns

It is axiomatic that, on a regional scale and before the railway age, the building materials in an area varied according to the underlying geology (Clifton-Taylor 1972). This "pattern of English building" arises because of the incentive to use local materials provided by high transport costs, particularly of stone and brick (Purcell 1967 chapter 11). But how closely do buildings reflect their underlying geology on a local scale?

Woodcock (2025 Fig. 6) showed that the distributions of two minor, but distinctively iron-rich, stone types in south Cambridgeshire closely correlate with local geology. Buildings with the mid-brown Ely Sandstone cluster around its Woburn Formation quarries at Ely and maybe Haddenham, although it was transported by river as far as 15 kms away. A dark brown Ferricrete, the 'Cottenham Sandstone' of King and Collins (2019), is restricted to the older terrace deposits of the River Cam from which it was probably sourced (Woodcock 2025 Fig. 6b). This section explores whether such correlations are apparent in the more common local stones in south Cambridgeshire churches – Clunch, Flint and Fieldstone – and also plots the spatial distribution of the imported Barnack Stone.

Data Analysis and Display

Clunch, Flint and Fieldstone make up nearly three-quarters of medieval rubble walls in the study area (Fig. 7e). The spatial distribution maps of walling stone (Fig. 11) plot the percentage contribution that these three stones make to the rubble walling in each church, using the assessment methods

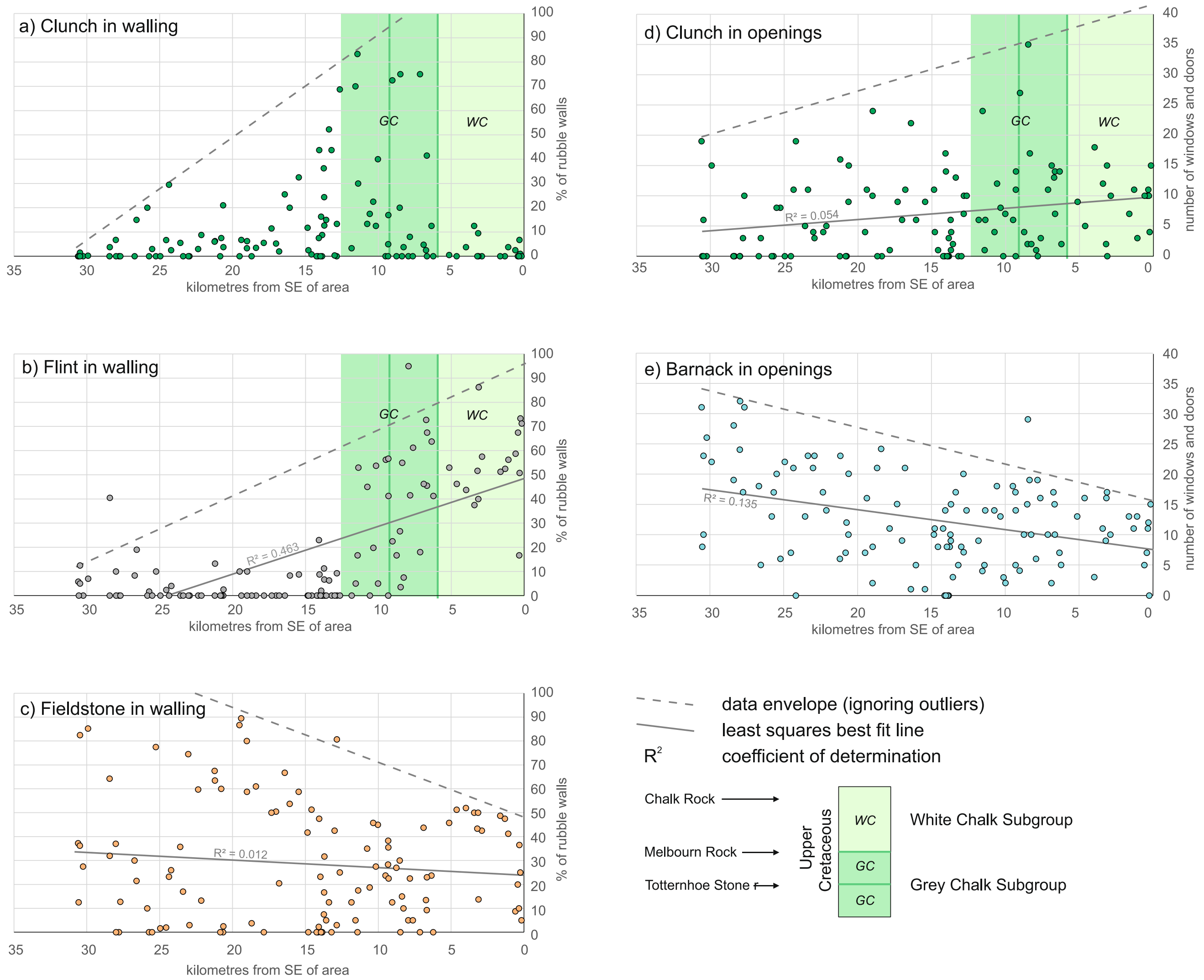


Fig. 12 Abundance of common stone types in churches plotted against distance from the southeast edge of the study area. Abundance of rubble walling stone is measured as the percentage of **a**) Clunch, **b**) Flint and **c**) Fieldstone in the rubble walls of each church. Abundance of stone for openings is measured as the number of windows and doors in each church that contain **d**) Clunch and **e**) Barnack

described in the methodology section. Each church appears as a circle on an appropriate base map, either of bedrock or superficial deposits (Fig. 11a, b, c). The area of the circle is proportional to the percentage contribution to that church, with the scale the same in each of the three maps. Churches with none of the plotted stone type are shown as a dot.

South Cambridgeshire church windows and doorways mostly comprised local Clunch and imported Barnack in the period 1066 to about 1500. Their volume in each church uses an imperfect but rapid assessment method: a count of the number of openings preserving each stone type. This method produces an underestimate of Clunch volume because it is likely to have been replaced by Victorian restorers. Barnack replacement is less likely, except for some mullions and sills where it is most vulnerable to weathering. Whatever, the distribution maps (Fig. 11d, e) show a circle for each church with an area proportional to the number of openings containing that stone. The base map is either the bedrock geology (Fig. 11d) or the present drainage system (Fig. 11e).

Spatial Patterns in Walling Stone

Clunch in rubble walling is common on the outcrop of the Grey Chalk Subgroup (Fig. 11a), presumably because it contains the durable Totternhoe Stone and directly underlies the hard Melbourn Rock. There is no obvious explanation for the cluster of significant Clunch use in the north of the study area at Little Thetford, Witchford and Wentworth. The low Clunch usage on the White Chalk Subgroup in the southeast of the area suggests that the subgroup's stone was nowhere

durable enough for construction, even the Chalk Rock in the middle of the unit.

Flint in walling is common on the outcrops of both the Grey Chalk and the White Chalk (Fig. 11b). Most of the Flint-rich walling to the northwest of the Chalk outcrop is the result of nineteenth century repair or addition, denoted as light grey circles on Fig. 11b. Only Mepal and Sutton in the north remain as anomalously rich in medieval Flint. The remaining pattern is consistent with the derivation of the church flints directly or indirectly from White Chalk bedrock, in which flints become more common stratigraphically upward and geographically south-eastward. However, most of the walling flints are either fractured or have lost their white cortex of highly silicified chalk; they have been geologically abraded, most likely by glacial or fluvio-glacial processes. The conclusion must be therefore that most walling flints are merely a distinctive variety of Fieldstone. A more detailed study of the compositional variation of walling Flint across the study area is needed to better constrain their provenance.

Fieldstone – other than Flint – in walling does not fit the bedrock geological template (Fig. 11c). Instead, Fieldstone is most common on superficial deposits, the till in the southwest of the area and the old river terraces, mainly of the Cam, that fan northward from the southern corner of the area. Soil profiles formed on these deposits came to incorporate cobbles, to be later exhumed as new arable fields were ploughed during the steady population growth between the Norman Conquest and the early fourteenth century famines and pandemics (Fig. 9d). There are almost no Fieldstone records on the peat or lacustrine deposits, both because they contain few cobbles and because no medieval churches were built on the then flooded peat lands.

Spatial Patterns in Stone Used for Dressings

Clunch in window dressings (Fig. 11d) is most abundant on the Grey Chalk Subgroup but was used more commonly than Clunch rubble both on the White Chalk to the southeast and on the Lower Cretaceous and Jurassic rocks to the northwest (Fig. 11a). The high quality Clunch used for these dressings presumably came from the Totternhoe Stone, also known locally as Burwell Rock (Fig. 11 key). The main quarry areas (Fig. 11d) were between Barrington and Haslingfield in the southwest, at (Cherry) Hinton, around Reach and Burwell, and at Isleham in the northeast.

Barnack was deployed in window and door dressings in almost every church in the area (Fig. 11e). It is more common than Clunch away from the Chalk outcrop; on the Lower Cretaceous and Jurassic clay lands to the northwest (Fig. 11d). Barnack stone was, of course, imported from the Lincolnshire Limestone belt between 45 and 75 kms away to the northwest (Fig. 1a). Transport mostly utilised the network of inland waterways across the Fens that existed before the major drainage schemes of the seventeenth century (Purcell 1967 Ch. 11; Chisholm 2010, 2011, 2021). The distribution map (Fig. 11e) is on a base map of the current river system in the study area, which – apart from the Bedford rivers – is not much different to its medieval pattern. This system, with smaller artificial cuts too small to show, was adequate to transport Barnack stone throughout most of the area.

The maps of numbers of openings (doors and windows) with Clunch or Barnack are just a first attempt at showing the medieval importance of these two stones. However, it has been observed qualitatively that a) the ratio of Barnack to Clunch varies markedly between churches, and b) Barnack use was prioritised first for vulnerable window components such as sills and hood moulds, then successively for mullions, jambs, arches and finally tracery. These observations need quantifying in a future project. The volume of Barnack stone used does not seem to relate to geography and may instead be related to the contemporary wealth of the church and parish. This hypothesis needs testing objectively.

Economics of Stone Distribution

Rubble-grade Clunch, and Fieldstone or Flint cobbles all had a relatively low *unit value* – the cost at the quarry or the field where the cobbles were collected. The transport costs of such a heavy commodity soon exceeded the unit cost, acting as an economic incentive to use the materials locally. Such a resource is said only to have a high *place value* – the economic importance attached to the location of a mineral deposit (Allaby 2020).The local-use incentive operated on scales of as little as ten kilometres in the study area, resulting in clustered distribution maps (Fig. 11a, b, c). This incentive for local use of high place-value resources has operated through history (e.g. Highley et al. 2004).

By contrast, the Barnack stone and best Clunch used for dressings were higher quality and scarcer resources. They had a higher unit value at the quarry and a correspondingly lower place value. The best Clunch was more evenly spread than Clunch rubble across the churches of the study area (Fig. 11a, d), being used throughout both the north-western clay lands and the White Chalk uplands in the southeast. Barnack stone was also dispersed across the study area (Fig. 11e) although it was slightly more abundant in the northwest where Clunch is less common. Barnack must have been regarded as an almost indispensable component of a medieval church, at least until the freestone ran out in the later fifteenth century.

The place value of a stone can be quantified by plotting the percentage of the stone in each church against the

across-strike distance measured from the southeast edge of the area (Fig. 12).

a) The plot for Clunch rubble (Fig. 12a) peaks between about 7 km and 13 km, corresponding to the likely source in the Grey Chalk Subgroup, including the Totternhoe Stone, and the immediately overlying Melbourn Rock. The frequency of Clunch rubble falls off either side of this peak. A linear envelope to the northwest decreases at about 4.3% per kilometre.
b) The plot for Flint rubble (Fig. 12b) peaks over the White Chalk Subgroup in the southeast, where bedrock Flint is most abundant. The envelope of Flint concentration falls off to the northwest at about 2.7%/km. This rate is nearly half that for Clunch and might be taken as evidence of its lower place value. However, it is probable that Flint does not have a simple line source in the southeast but was at least partly derived from regolith to the bedrock Chalk or from flints transported by ice or rivers.
c) Because Fieldstone rubble was evidently sourced from irregular patches of superficial deposits its plot of percentage versus across-strike distance (Fig. 12c) shows no strong pattern. The southeastward decrease in abundance of about 2.3%/km across the Chalk outcrop, between 15 and 0 km, probably just balances the increase in Flint percentage in the same direction.
d) The plot for high quality Clunch in dressings (Fig. 12d), like the Clunch rubble, shows a peak at 8–9 km, about the position of the source of Totternhoe Stone. The data envelope slopes to the northwest from here at a rate of about 0.71 windows per kilometre. These units cannot be directly compared with the envelope gradient of rubble Clunch (Fig. 12a).
e) The plot for Barnack in dressings (Fig. 12e), perhaps unexpectedly given its distant source, shows an organised decrease in abundance towards the southeast at a rate of about 0.60 windows/km. This pattern partly balances the southeastward increase in Clunch abundance and may also reflect the increasing transport costs of Barnack in that direction.

The quantitative analysis shows that the high place-value material for rubble walls was derived locally. Clunch rubble was rarely transported more than 20 kms from its source whereas high-quality Clunch for dressings was transported further than this to outside the study area. Barnack for dressings had already travelled a straight-line distance of 40 km to reach the northwest edge of the study area and had to travel a further 30 km to reach its southeast edge.

The analysis of the decrease in abundance of stone with distance from its supposed source can be compared with the analysis of Norfolk stone by Allen (2004, e.g. Figures 3.3, 3.6). Although the abundance units used by Allen were more qualitative, his data for Clunch rubble decrease to near zero about 20 kms from the outcrop, a distance similar to the Cambridgeshire study area.

Discussion

Despite the significant conclusions from the south Cambridgeshire study, a number of important questions remain for future research:

a) How was the use of expensive Barnack freestone prioritised in a medieval church? It has previously been suggested that Barnack was used in a particular order of priority in dressings in both walls and openings. These hypotheses need more rigorous testing.
b) Can the medieval wealth of a church be assessed from the total amount of Barnack Stone in the church or from the proportion of Barnack to Clunch in the door and window dressings? What factors influenced this wealth distribution? A crude measure from the present study is the number of openings – doors and windows – that

Table 1 The ten richest churches in the study area, based on the number of doors and windows that contain Barnack Stone. Ely Cathedral is excluded but would easily top the list with over 200 openings (doors + windows)

Church	*Openings containing Barnack*	*Notes*
Over, St Mary	32	belonged to Ramsey Abbey
Bluntisham, St Mary	31	
Swavesey, St Andrew	31	part of a C13 Benedictine priory
Bottisham, Holy Trinity	29	
Haddenham, Holy Trinity	28	belonged to Ely Cathedral
Sutton, St Andrew	28	belonged to Ely Cathedral
Fenstanton, St Peter & St Paul	26	
Girton, St Andrew	24	belonged to Ramsey Abbey
Witcham, St Martin	24	belonged to Ely Cathedral
Bourn, St Helen and St Mary	23	site of C11 castle of Barony of Picot

incorporate Barnack. On this basis, the top ten churches in this medieval 'rich list' (Table 1) include six with close ties to a Fenland abbey. Given that these Fenland abbeys influenced the cost of Barnack Stone by levying tolls on its overland and water transport (Everson and Stocker 2019), this likely determinant of Barnack distribution warrants further testing.

c) What volume of Barnack Stone was used in a typical south Cambridgeshire church and therefore in the study area as a whole? These estimates could be multiplied up over the whole of the Fen Basin area of Barnack use to give an estimate of the amount of stone exported from the Barnack quarries. This important aspect of the medieval economy deserves future attention.

d) Why was no other Lincolnshire Limestone than Barnack used in medieval churches until after Barnack freestone was exhausted in the mid-fifteenth century? Everson and Stocker (2019 p.132) have argued that Peterborough Abbey, in particular, had an interest in the use of stone for building churches that was not just economic but symbolic and liturgical. St Peter's name (Petrus = rock) marked him out as the spiritual foundation of the earthly church. This medieval view explains the very widespread use of Barnack freestone for church dressings throughout the Fen Basin (e.g. Harris 1990; Historic England 2023b) but not its complete dominance over other equally suitable stones types such as Weldon, Ketton, Clipsham or Ancaster. Presumably these substitute stones were not blessed by the medieval church with the same spiritual value as Barnack?

Conclusions

1. A semi-quantitative field survey has been made of building stone use through time in 124 medieval churches, predominantly in south Cambridgeshire.
2. The Pre-Reformation churches of this area mostly had rubble walls of local Fieldstone (typically flint-rich), local Clunch (Cretaceous Chalk), and imported Jurassic limestone from Barnack. Less common were ashlar walls of Clunch or Barnack.
3. Medieval dressings were mostly imported Barnack Stone for exposed locations and local Clunch in more sheltered positions. The amount of Barnack used in windows and doors is probably a good indicator of a church's medieval wealth.
4. Dressings of Clunch were much repaired or wholly replaced during the nineteenth century church 'restorations.' The replacement stone came mostly from the Jurassic Lincolnshire Limestone belt, not from Barnack but from other quarries along its whole length from Weldon to Ancaster.
5. The Victorian restorers also removed much of the render that probably coated most medieval rubble walls; only about 10% of walls retain their traditional coating or have had it re-instated.
6. The Cambridgeshire case study exemplifies the medieval use of local materials where they sufficed for less exposed situations, but the import of more weather-resistant stone for exposed locations. The use of Barnack was despite the transport costs for the inland waterway journey of over 100 kms.
7. The methodology used in the Cambridgeshire study could be used for building stone studies of medieval churches elsewhere, in the UK or abroad.

Appendix 1

List of the 124 medieval churches in the study area.

Babraham St Peter
Barnwell St Andrew the Less
Barrington All Saints
Barton St Peter
Barway St Nicholas
Bluntisham St Mary
Bottisham Holy Trinity
Bourn St Helen and St Mary
Boxworth St Peter
Burwell St Mary
Caldecote (Cambs) St Michael and All Angels
Cambridge Holy Sepulchre
Cambridge Holy Trinity
Cambridge St Bene't
Cambridge St Botolph
Cambridge St Clement
Cambridge St Edward
Cambridge St Mary the Great
Cambridge St Mary the Less
Cambridge St Michael
Cambridge St Peter
(Cherry) Hinton St Andrew
Chesterton St Andrew
Chettisham St Michael & All Angels
Chippenham St Margaret
Comberton St Mary
Conington St Mary
Coton St Peter
Cottenham All Saints
Coveney St Peter ad Vincula

Denny Abbey Church
Dry Drayton St Peter and St Paul
Dullingham St Mary
Duxford Chapel
Duxford St John the Baptist
Duxford St Peter
Elsworth Holy Trinity
Ely St Mary
Exning St Martin
Fen Ditton St Mary
Fen Drayton St Mary
Fenstanton St Peter & St Paul
Fordham St Peter and St Mary Magdalene
Fowlmere St Mary
Foxton St Laurence
Freckenham St Andrew
Fulbourn St Vigor
Girton St Andrew
Grantchester St Andrew and St Mary
Great Abington St Mary
Great Eversden St Mary
Great Shelford St Mary
Great Wilbraham St Nicholas
Haddenham Holy Trinity
Hardwick St Mary
Harlton Assumption of the Blessed Virgin Mary
Harston All Saints
Haslingfield All Saints
Hauxton St Edmund
Hildersham Holy Trinity
Hilton St Mary Magdalene
Hinxton St Mary and St John the Evangelist
Histon St Andrew
Holywell St John Baptist
Horningsea St Peter
Ickleton St Mary Magdalene
Impington St Andrew
Isleham St Andrew
Isleham St Margaret
Kennett St Nicholas
Kingston All Saints and St Andrew
Knapwell All Saints
Landbeach All Saints
Landwade St Nicholas
Little Abington St Mary
Little Downham St Leonard
Little Eversden St Helen
Little Shelford All Saints
Little Thetford St George
Little Wilbraham St John the Evangelist
Littleport St George
Lolworth All Saints
Longstanton All Saints
Longstanton St Michael
Madingley St Mary Magdalene
Mepal St Mary
Milton All Saints
Moulton St Peter
Newton St Margaret
Oakington St Andrew
Over St Mary
Pampisford St John the Baptist
Papworth Everard St Peter
Papworth St Agnes St John the Baptist
Rampton All Saints
Sawston St Mary
Snailwell St Peter
Soham St Andrew
Stapleford St Andrew
Stetchworth St Peter
Stourbridge St Mary Magdalene
Stow cum Quy St Mary
Stretham St James
Stuntney Holy Cross
Sutton St Andrew
Swaffham Bulbeck St Mary
Swaffham Prior St Cyriac and St Julitta
Swaffham Prior St Mary
Swavesey St Andrew
Teversham All Saints
Thriplow St George
Toft St Andrew
Trumpington St Mary & St Michael
Waterbeach St John the Evangelist
Wentworth St Peter
Westley Waterless St Mary
Whittlesford St Mary and St Andrew
Wicken St Laurence
Wilburton St Peter
Willingham St Mary and All Saints
Witcham St Martin
Witchford St Andrew
Worlington All Saints
Yelling Holy Cross

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