

ROMANESQUE LINEAR MEASURES OF ENGLAND AND CONTINENTAL EUROPE

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'I lifted up mine eyes again and looked, and beheld a man with a measuring line in his hand. Then said I, Whither goest thou? And he said unto me, To measure Jerusalem, to see what is the breadth thereof, and what is the length thereof

Zechariah 2. 1- 2

The initial aim was to determine what linear measure, if any, the masons of Norman England used to craft their stonework. Some 3600 dimensions of smaller Norman features were measured and analysis showed conclusively that a foot close to 280 mm was the main measure used for this work.

In considering the origin of this hitherto unsuspected foot, an Anglo-Saxon foot of c. 335 mm, labelled here the 'longer foot', together with this c. 280 mm foot, the 'shorter foot', and the current Standard English foot of 304.8 mm have been linked to the familiar rod, pole or perch of 5.5 yards or 5.03 m, four of which are the length of a cricket pitch.

Modest inroads into European Romanesque, have identified use of both these feet, and it seems that the 'shorter foot' supplanted the 'longer'. The 5.03 m perch may have had a stronger influence on European metrology than hitherto recognised.

A method was developed for wresting the measures from the data without the constraints of traditional metrology. That finally evolved is simple to operate and has the necessary robustness to deal with data that is not exact.

THE PROJECT

It is recognised that the work described below has a number of loose ends, but in view of the antiquity of the researcher, it was felt that it was more important to reveal the main findings now, than run the risk of the research and its records being consigned to obscurity, which might otherwise occur.

The work was initiated when, as a field-worker for the Corpus of Romanesque Sculpture in Britain and Ireland, recording plinths, bases, capitals etc., I mused over whether they were moulded to a metrological discipline, or just happened.

A trawl through some of the literature was generally unhelpful. John Harvey mentioned that in many parts of Europe during the dark ages, the Roman *pes* of 296 mm had remained the standard measurement;¹ this was supported by Peter Kidson who said, in connection with Salisbury Cathedral, that there was good reason to suppose that the Roman foot was still known and used in various parts of medieval Europe, including areas just across the Channel.² There are claims by Hurst of the use of the Roman *pes* at Bordesley Abbey and other Cistercian sites.³ Greene also claimed this value for Norton Priory. Skinner stated that up to the twelfth century, a foot of 316.75 mm was used in England, but he also mentioned that a perch of 15 feet gave a foot of 335 mm.⁴ Bagshaw, in 2000 found seven scratch marks on a block at the south end of Gloucester Cathedral which, assuming they represented inches, would give a foot of 324 mm; the block concerned was taken from Roman town of *Glevum* and may be Romano-British rather than Romanesque.⁵

No justification for the measures claimed in most of the above statements were given, and to all intents and purposes there appeared to be no consolidated study or opinion regarding the measure used in Norman England, nor indeed in the wider

Romanesque world. There was thus an opportunity to determine whether there was a consistent measure in use, with a caveat from Flinders Petrie (1853-1942), who believed that a lost measure could never be recovered by analytical means.⁶ Nevertheless, and more out of curiosity than the intention to create a project, an opportunistic study was made in 2002 of the crossing piers, in plan, at St Nicholas' church, Old Shoreham, Sussex, (Fig. 1).

The four piers are symmetrical (Fig. 2), although handed, and it was noted that a mean dimension of 562 mm and its approximate half value of 285 mm often appear. A histogram plot of all the dimensions showed that they fell into discrete groups, rather than an amorphous lump, leading to the conclusions that the piers were moulded to a system of measurements rather than just happening, and that a length of about 280 mm was important. A measure of about this length was a worthy candidate for a foot, which, based on anatomy, was deemed to lie within the limits of 250-350 mm. When a similar possible foot was found in dimensions of the crossing at East Meon, a project seemed viable. Measurements of mainly Norman piers and multi-ordered doorways followed, these generally pointing to this key measurement of about 280 mm.



Photo: Author

Fig. 1. St Nicholas', Old Shoreham, north-east crossing pier.

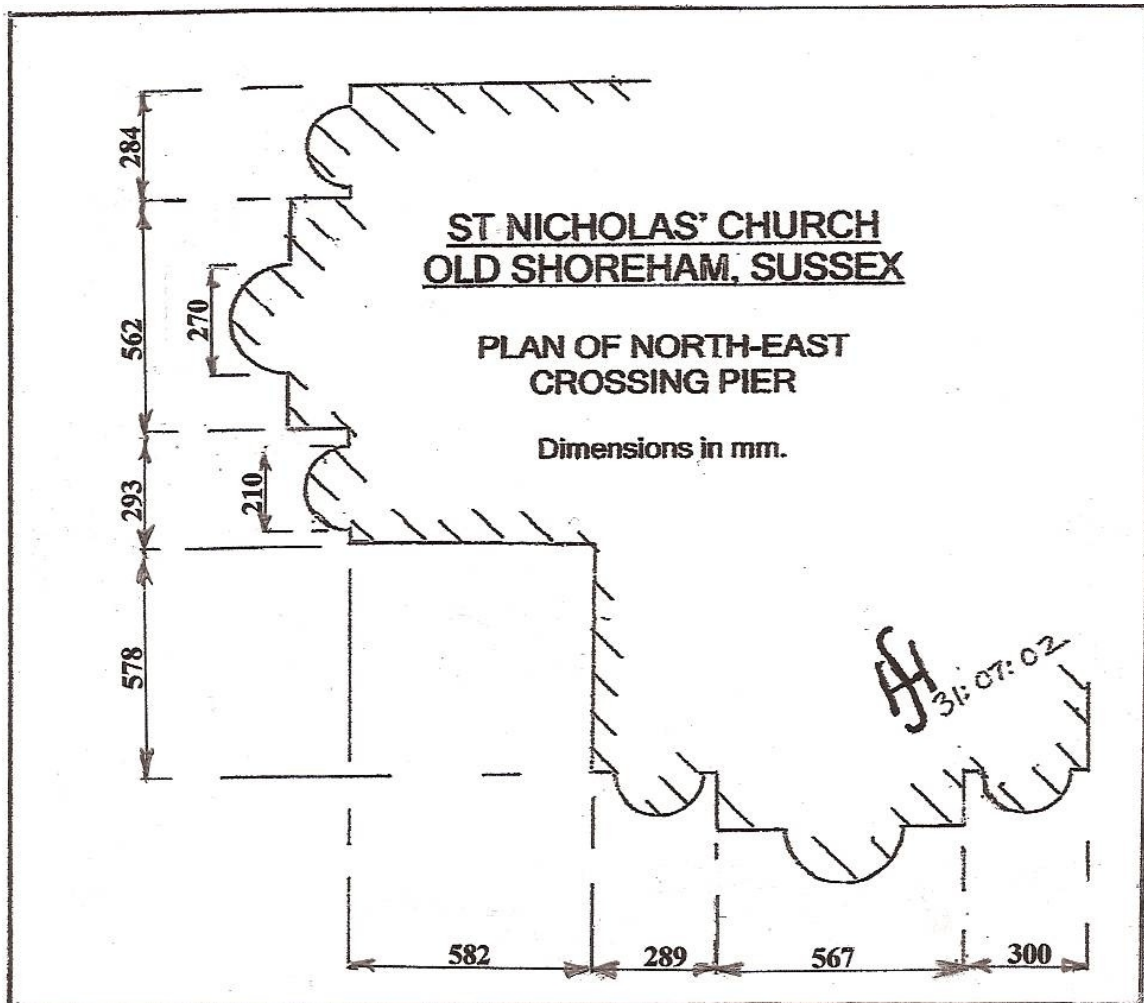


Fig. 2. Old Shoreham crossing pier in plan.

At about this time, Eric Fernie drew my attention to a similar foot claimed by Fred Bettess, who identified a 280 mm unit from a few features of the Anglo-Saxon church of St Paul, Jarrow. After investigating his claim, I sadly had reservations about both his method and result.⁷

The discovery of a *c.* 280 mm foot was duly reported to a meeting of the *Corpus Romanesque* in 2004 where perhaps there was some lack of enthusiasm.⁸ This was not entirely unexpected as the presentation was necessarily somewhat arithmetical, and practical metrologists generally have had a bad press. In 1971 Philip Grierson wrote: 'In contrast to historical metrologists are others who base their conclusions upon what I can only term mathematical romanticism and diffusionism run mad'.⁹

Work on the project nevertheless continued, concentrating on the consolidation of the value of the *foot*, and devising methods of extracting values from individual sites.

ANALYTICAL METHODOLOGY

It is emphasised that the analysis uses measured data only, without any assumptions as to what the outcome might be. From the outset, it was decided that only shorter lengths, no more than about a metre in length should be considered. This decision was made in the light of the problem that Peter Kidson found at Salisbury Cathedral; he encountered a measurement of 39 standard feet, and wondered whether it was meant to be 40 Roman feet.¹⁰ Longer lengths can too readily be adapted to fit any preferred system of measurement unless constraints are placed on their interpretation, as discussed below. With smaller dimensions, up to a metre or so, there is less scope for this, and there is the prospect that the foot will identify itself from among the measurements.

The second requirement was to obtain as much data as possible to ensure a reliable and wider picture; thus about 3,600 measurements have been recorded from fifty-four Anglo-Norman sites. Few of these were especially selected as the project was based mainly on windows of opportunity, largely in the Midlands and South-east.

The measurements were made of repeated features, such as the plan profiles of arcade piers and the stepped orders of doorways. Most were obtained using no more than a simple expanding tape. Usually it was only reasonable to measure to the nearest centimetre because the features themselves were seldom more consistent than that. Subsequent calculations were also carried out in centimetres, a measure with which I am the most comfortable, avoiding giving an impression of great accuracy as does working in millimetres.

To avoid confusion with the standard foot of 304.8 mm, in the following, the word 'foot' relating to that sought, with its derivatives and abbreviations, is printed in italics.

Ranking and Determination of Means.

The measurements made on a particular site were usually aggregated, unless more than one foot value might be expected, as discussed below for Worcester crypt, for example. The measurements were then ranked, when usually, but not invariably, the data formed discrete groups. These could have ranges of tens of millimetres, but provided they were adequately separated from the next group, they were accepted, and their mean values were found. These means became the working data, together with their frequency, ie the number of measurements forming a particular mean.

Global Plot

In dealing with a large number of measured means, one is looking for some periodicity in the data, representing nodal points, such as feet, and harmonics, such as halves, thirds or

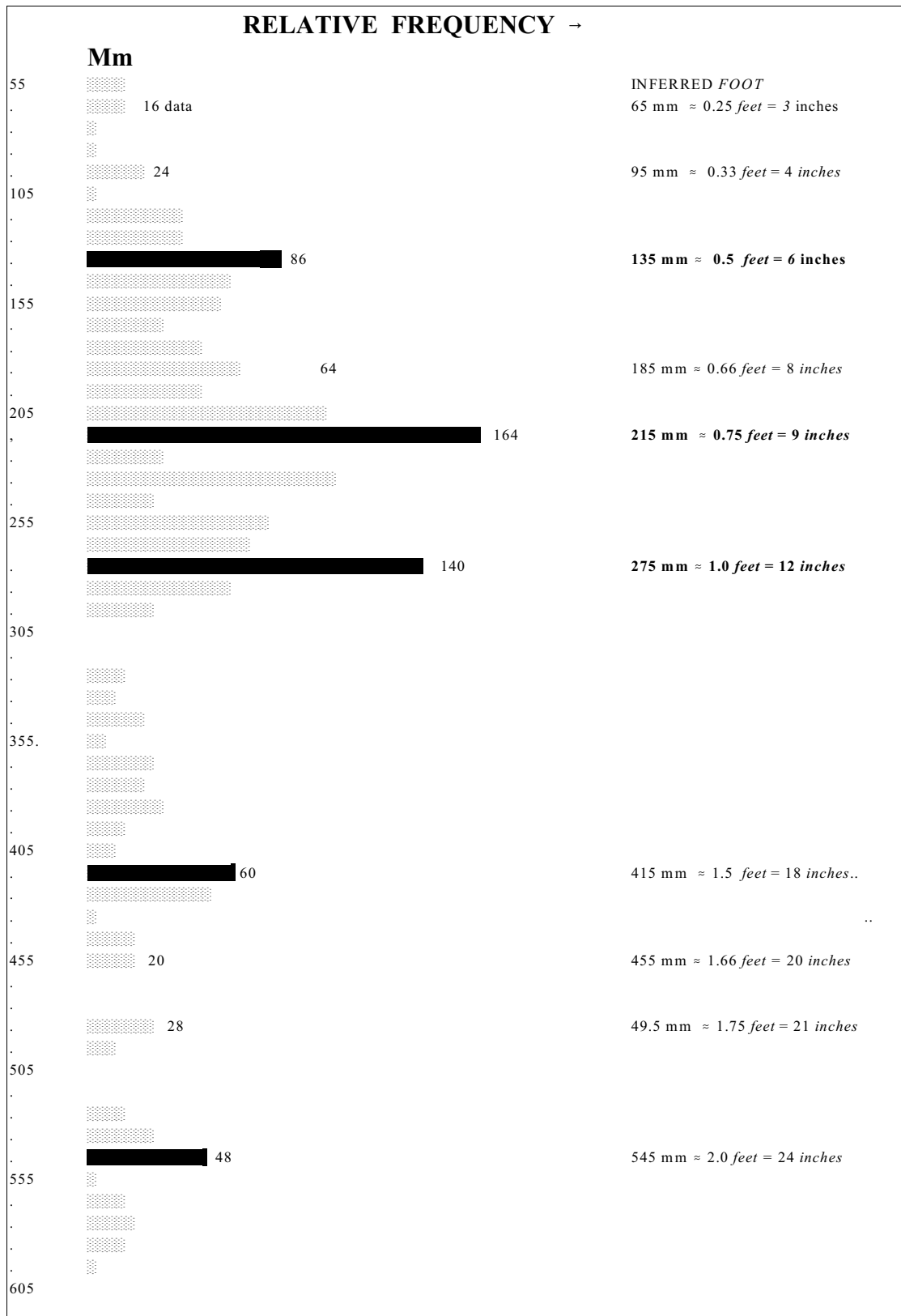


Fig. 3. 'Global Plot' of means of all English data. A provisional *foot value* of 275 mm has been assumed for the purpose of identifying the peaks.

quarters of feet, or whatever the system may be. The simplest and most effective method of analysing all the data is by means of a 'global plot'. This is simply a histogram (set on its side for convenience) in this instance with blocks of data at 10 mm intervals, with their lengths representing their respective frequencies of

occurrence. The reason the ordinates of the plot are, for instance, 205, rather than 200 mm, is that 205 includes all data means between 200 and 209.9 mm.

The global plot (Fig. 3), based on some 3,300 measurements from England, shows some clear peaks, the largest of which is at 215mm, represented by one hundred and sixty four items of data, closely followed by 275 mm, with one hundred and forty

As mentioned above, it had been decided limit the search for a likely *foot* type unit to between 250 and 350 mm, and here the only one significant peak in that range is at 275 mm. Further, inspection of the other main peaks revealed a structure of ratios relative to 275 mm as shown (Fig 3.). For instance, the 24 results at 95 mm are close to 0.33 *feet* or 4 *inches*, and so on.

A more detailed method of data analysis is discussed below, but it is sufficient here to state that the resultant mean *foot* derived from the global plot data was 277 mm.

Thus by means of this simple approach (and many measurements!), it was shown that a *foot* of *c.* 280 mm was used for the mouldings of Norman buildings in central and southern England (*c.*280mm was chosen as the provisional value of this *foot* as successive analyses of global plots, as the data increased, tended towards this value). The strong presence of halves, quarters and thirds of *feet* is to be noted. These are referred to as ‘the regulars’ as opposed to the remaining parts of the foot, ie 1, 2, 5, 7, 10 and 11 *inches*, dubbed the ‘strays’ which in a random situation should have an equality of presence.

Obviously this kind of plot is only successful if the great majority of the data belong to one system of measure. In this case there is another minority measure present, in sufficiently small numbers not to influence the general pattern unduly, but it does explain the presence of some of the spurious peaks. There are, of course, other causes why the diagram is not perfect, such as deviations from the design, and lengths that are not necessarily to specified dimensions, not to mention survey errors. There is a significant peak at 235 mm which corresponds to 10 inches of a 280 mm foot this being an exceptional ‘stray’. Nevertheless, within the range of 250 to 350 mm, the majority presence of a *c.* 280 mm *foot* emerges quite clearly.

ANALYSIS AT SITE LEVEL

Having established a measure from the global plot, the project might well have been wound down. However, the need was felt to be able to identify, with some confidence, the value used at individual sites in order to confirm or otherwise, the use of the established measure. This led to the development of the methodology that is now used for the analysis of site data in general

This method is an important metrological tool and is described in detail in the Appendix, together with a worked example. In essence, groups are sought within the site data that bear a simple ratio relationship to each other, such as two to one, three to two etc. These become the key data. The question is then asked ‘what inches of what foot could these represent?’ This is referred to as ‘Option Analysis’. Applying certain rules of analysis (such as the foot will lie between 250 and 350 mm) to the several solutions all but one are hopefully eliminated. A key to the success of this method is the use of shorter measurements, which restricts the number of options possible.

Results from Site Analysis

Sixty two English sites have been surveyed to a greater or lesser degree. The full list is tedious, but include, with their evaluated *foot* values, Christchurch Priory,

Hampshire (291 mm) Melbourne church, Derbyshire (287 mm), Old Shoreham, Sussex (286mm), Oxford Christchurch (284 mm), St Albans Cathedral (274 mm), St Cross, Winchester (281 mm), Priory of St. Bartholomew, Smithfield (274 mm), Southwell Minster (273 mm), Tewkesbury Abbey (280 mm) and Winchester Cathedral (272 m). The histogram (Fig. 4) shows the distribution of the evaluated *foot* in 10 mm steps from all the results. One is immediately struck by the fact there are two groups, the main with a mode at 280 mm, and a smaller at 335 mm.

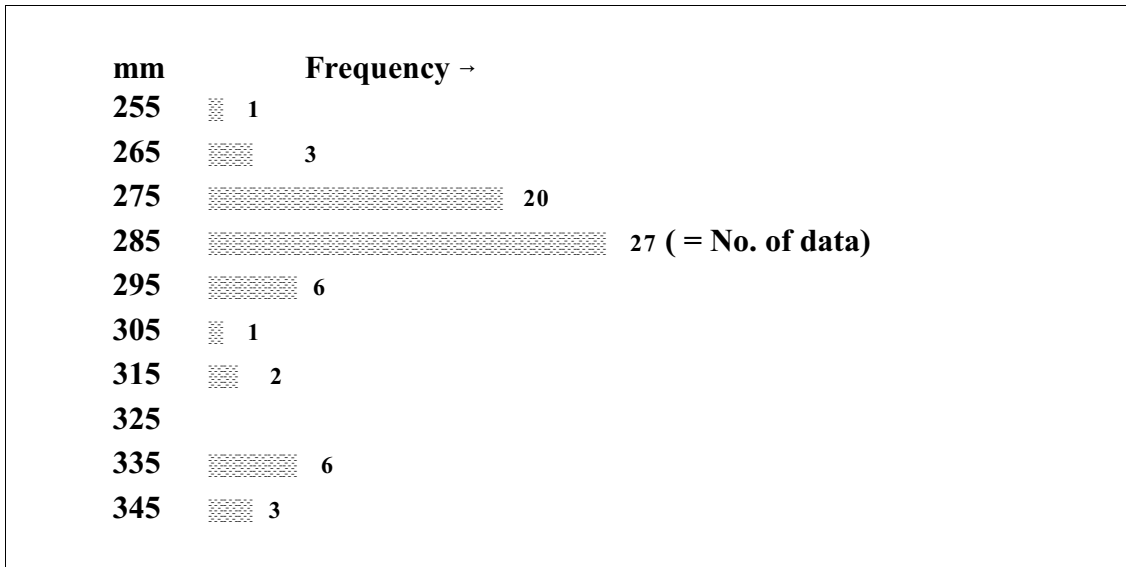


Fig. 4. Histogram of English *foot* values from 65 locations.

The main upper group with a mode of 285 mm is of no surprise, and conforms to the global plot. The actual weighted average (taking the relative frequencies into account) was 279 mm. There is a small group hovering around 305 mm, that may be associated with the Standard foot, but are too small a group to be of immediate consequence, although they are associated with Shropshire and Herefordshire, for which few results have so far been obtained. Alternatively, they are associated with the Roman *pes* of 296 mm. There is scope for some interesting work here.

The lower group are quite separate with a mode of 335 mm and a weighted average of 336 mm. These are discussed under the origins of the 280 mm foot, below.

Sub-units of the Foot

In the course of analysing the ratios, 263 values of the *inches* used were identified. The histogram (Fig. 5) shows how they were distributed within the *foot*. For example, the frequency of occurrence of integer feet (ie zero inches) was 25%, but of 7 *inches*, only 1%. It is on the basis of this distribution that Rule 2 (*see* Appendix), for the eliminations of options was devised.

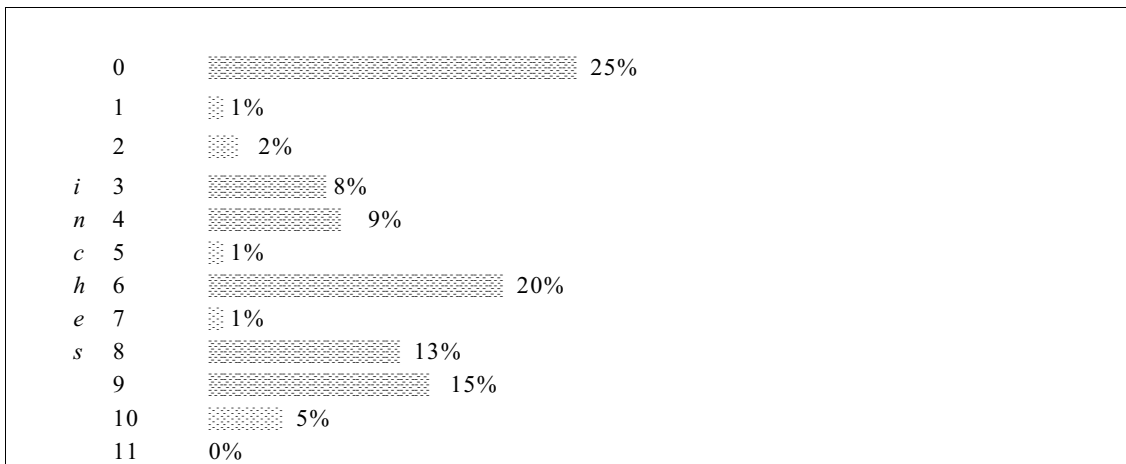


Fig. 5. Histogram of the distribution of *inches*.

Utilisation of Data

It was not possible to extract a result from eleven sites, and for most of the others not all the data could be used. The reasons for this include the data not falling into discrete groups, and also the lack of simple ratios. The average of usable data was 54%.

Standardisation

As seen from the histogram (Fig. 4), the values of the *foot* extracted from the various sites spread over a range, varying from 265 to 295 mm, but arguments as to why one site might yield a value of, say, 272 mm and another, say, 285 mm is generally nugatory as the means are derived from groups of spread measurements, and are subject to error. Grierson mentions that iron rods were used to convey the measure from place to place, and no doubt these were copied, also giving rise to error.⁹

Obviously, some differences or errors arose from the mason's ability, inclination or need to work closely to the measure. Whilst the master mason used a measure to set out his design, provided that all faces and edges in the final structure were aligned, he would not be concerned unduly if the moulding did not exactly match his plans, as close tolerances were not needed. As an example of the sampling repeatability that might be expected, two sites, St Nicholas' at Old Shoreham and St Mary de Haura at New Shoreham, were revisited after an interval of six years and the crossing piers re-measured. St Nicholas', the first site in the project to be measured, initially gave a *foot* of 286 mm; the recent re-measure gave 285 mm. St Mary de Haura gave respectively 279 and 280 mm. This was unexpectedly good agreement.

THE ORIGINS OF THE *c.* 280 mm *FOOT*

The question now turned to whether an explanation could be found for this nominal 280 mm foot. An Anglo-Saxon 'Yeaving foot' of 281 mm, was proposed by Hope-Taylor in his study of the Northumbrian Palace, but this was discounted by Fernie on the grounds that that it was 'restricted to one site and it had no independent existence, either in texts or among surviving measuring rods'.¹¹ A review of this, however, may now be in order.

Due to its proximity to the Roman *pes*, the 280 mm *foot* was initially considered to be somehow related, and suggestions were made at the *Corpus Romanesque* meeting, mentioned above, that the stonework was cut to dimensions at the quarry,

and then dressed *in situ*, reducing the effective *foot*. There are, however, better explanations.

Turning to the Anglo-Saxon scene, in the 1980s, both Peter Huggins and Warwick Rodwell noted the presence of a recurrent measure of 5.03 m between post centres in the ground plans of Anglo-Saxon buildings.^{12, 13} This happens to be the value of the rod, pole or perch that used to be defined on the back of school exercise books, until it was finally abolished in 1961 (but four of which are still the length of a cricket pitch).¹⁴ Huggins explored the idea of dividing this perch into fifteen units, postulating that each could equate to the *manupes*, a hand-foot that comprised two hand-widths with outstretched thumbs, amounting to 335 mm.¹⁵ This *manupes*, and half its value, the *shaftment*, he argued, is recorded as going back to the ninth century and therefore it is permissible to consider such a relationship, and this is now generally accepted.

On the basis of Huggins' assertion that there is an Anglo-Saxon *foot* of some 335 mm derived from one fifteenth of the 5.03 m perch (and there are various sized perches), I noted that a *c.* 280 mm *foot* was one eighteenth of the same perch. To cap this, Huggins, in our discussions, noted that the present foot of 304.6 mm, confirmed at Richard I's Assize of 1196, was one sixteenth and half of the perch, almost exactly half-way between the two – a compromise measure and strongly suggests the origin of our current foot.. This was almost too neat to be true, but this is the perch family tree (Fig. 6) that we now postulate. The documentary evidence is wanting, but the practical evidence is strong.

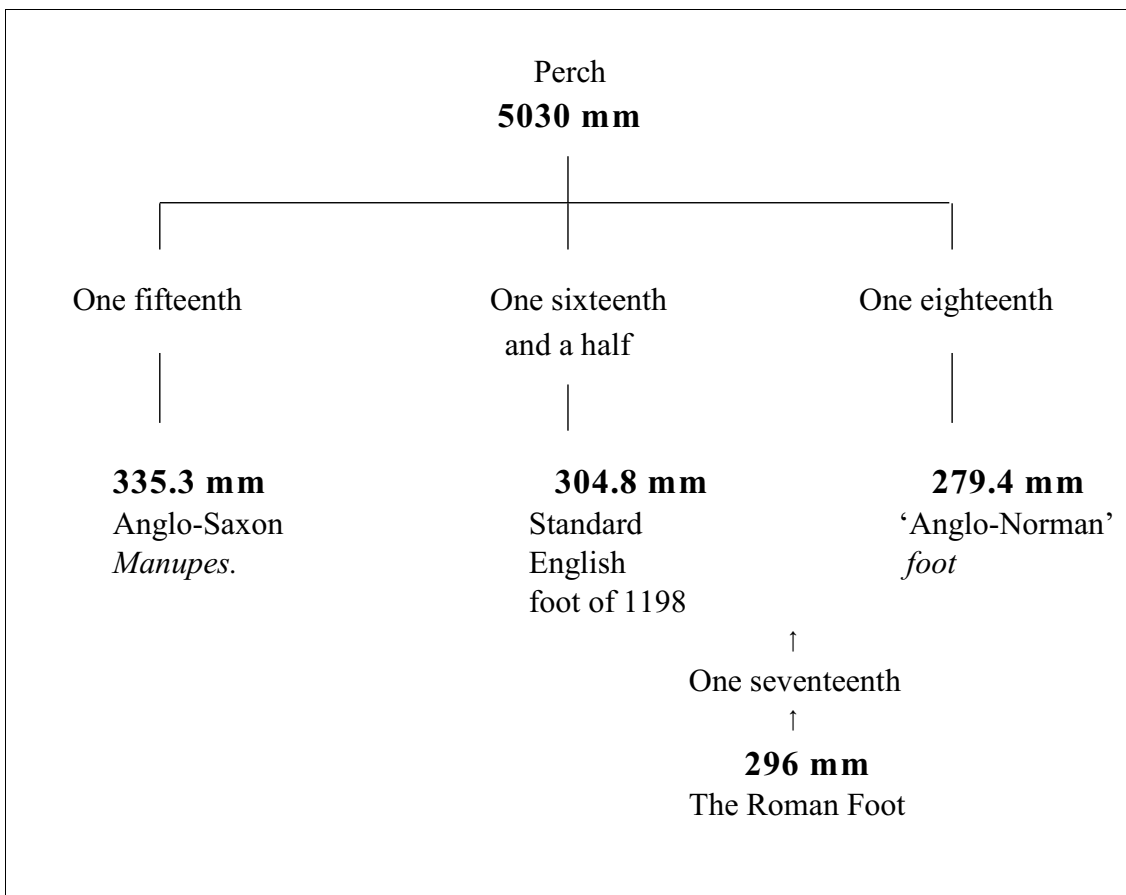


Fig. 6. The 'perch' family tree.

The next question, of course, is what was the origin of the 5.03 metre perch? The perch, or *pertica*, had a role in Roman metrology but it was of variable value, and whether this included 5.03 m seems a matter of debate although Eric Fernie has

observed that the 5.03 m perch equates to seventeen Roman *pes*. This is a matter I leave for the historical metrologists to sort out.

For convenience and within the context of this paper only, the *c* 280 mm *foot* is henceforth referred to as the ‘shorter foot’ and the *c*.335 mm *foot* as the ‘longer foot’. This also avoids, for instance, the need to be too pedantic over whether to designate the ‘shorter foot’, as *c.* 280 mm or 279.4 mm. Adoption for general use, however, would require a pre-fix, but it is uncertain what this should be. The prefix ‘Romanesque’ might be too limiting, even taking ‘Romanesque’ in its widest sense.

An important question remains; if the Anglo-Saxons were using the ‘longer foot’, where did the ‘shorter foot’ come from? An hypothesis that it could have come over with the Conqueror was tested, and a survey of the nave piers of the Conqueror’s Abbey of S. Etienne at Caen gave a *foot* of 277 mm with the highest confidence (*see* the Appendix). However, before a foot of *c.* 280mm can be claimed to have been adopted in England only after the Conquest, it is necessary to demonstrate that it was not used beforehand. Unfortunately, Anglo-Saxon stone buildings have a lack of moulded features of the kind used to obtain the Norman result. Nevertheless a handful of surveys to date have yielded results as varied as 332, 308 and 280 mm. Thus the answer is in abeyance.

Attention was now turned to mainland Europe.

RESULTS FROM MAINLAND EUROPE.

French, Spanish and Sardinian Sites

In France, apart from the results from Caen, opportunistic surveys were made of other Romanesque churches mainly in Normandy, Burgundy (including Vezelay, Fontenay and Paray-le-Monial) and its neighbour to the east, the Jura. One church each in Savoy and the Pyrenees Atlantique was also sampled. The paucity of data is regretted, but opportunities have been limited. In all, twenty-five sites have been studied (three not yielding results) with a total of over 1700 measurements.

The resulting histogram (Fig. 7) shows, once again, that there are two measures at play, and comparing their weighted means (taking frequency of occurrence into account) with the model (Fig. 6.) the actual results are 277 against 279.2 mm, and 330 against 335 mm. There are, however, far too few data to determine a pattern of their relative use, although there is a hint, as in England, that the 335 preceded the 280 mm, as will be discussed below. They are certainly not geographically arranged; in Normandy, S. Etienne at Caen gave a value of 277 mm against nearby S. Martin at Cruelly, 20 km away, yielded 329 mm.

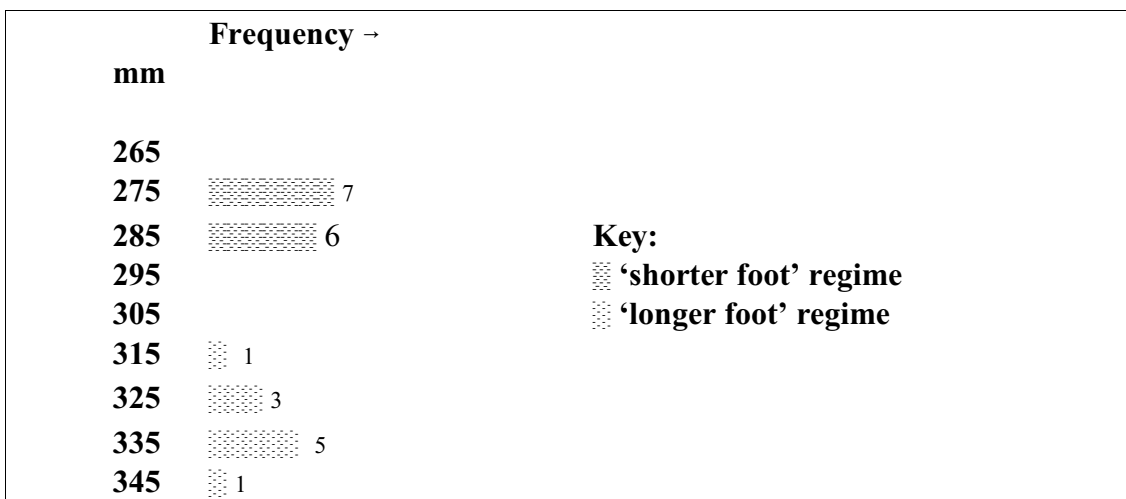


Fig. 7. Results from 23 French Sites.

585 measurements have also been obtained from eleven Romanesque sites in Spain, again on an opportunistic basis mainly in the Pyrenean region, including the Monastery at Leyre (339 in the crypt and 327 mm in the church), the Cathedral at Seo Urgell (333 mm) the monastery at Cangas (305 mm) and the cloisters at Soria (337 mm). A sole result at 270 mm was from the church in the small town of Sigüés in the Pyrenean foothills. For these Spanish sites there is a clear dominance of the ‘longer foot’. Importantly, at all sites, there were measurements present that corresponded to the evaluated foot..

In addition two Romanesque sites in Sardinia were surveyed, the basilica at Porto Torres (332 mm), and the simple church at Bosa (336mm). It is recognised that in isolation, the Sardinian results would be of little value, but taken in with other Romanesque data, they carry some weight. At the risk of labouring the point with regard to two values of the *foot*, a histogram (Fig. 8) shows all the European results, by country. Whilst there are some strays, the dominance of the ‘longer’ and ‘shorter’ feet, is unquestionable.

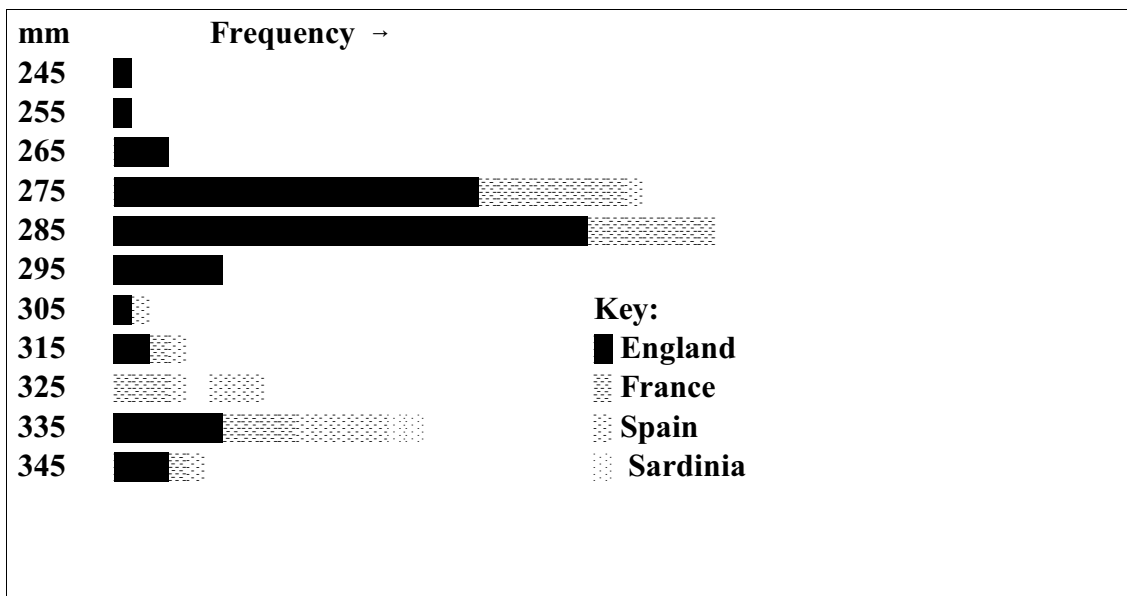


Fig. 9. Histogram of all European *foot* results by country.

LONGER LENGTHS

Thus far, only shorter lengths from the orders of doorways, piers etc., up to a metre or so in length, have been considered. This has avoided a multitude of indeterminable alternatives for Optional Analysis (as detailed in the Appendix). The question now is whether the *foot* can be evaluated from longer lengths, such as from the layouts of churches.

An analysis was carried out on 29 dimensions provided by Eric Fernie from the Abbey of S Etienne, Caen. These included nave length, aisle widths, buttress widths etc., dimensions up to 76 metres in length. Having found some ratios, the corresponding key dimensions were evaluated in the usual way, deriving a basic unit of 1.414 m. For the purpose of Option Analysis, this is an order higher than normally encountered. Limiting the possible *foot* to between 250 and 350 mm, and working at *inch* level, there are 24 possible solutions that cannot be resolved. However, this situation can be alleviated by assuming that the basic unit is an integer *foot*. This approach led to possible *feet* of 355, 282 or 236 mm; the only value in range (see Appendix, Rule 1.) being 282 mm.¹⁶ As the mouldings at Caen had yielded a foot of 277 mm, this is both a convenient and likely result, indicating that in this case the assumption of integer feet only was justified.

According to Hurst, as stated above, Bordesley Abbey used the Roman *pes* of 296 mm ‘like all Cistercian Abbeys’.³ Using his data, and assuming that the key dimensions forming ratios were integer values of a *foot*; a result of 296 mm for the layout *foot* was obtained. This agrees with Hurst’s findings and suggests that the Roman foot of 296 mm, referred to there as the ‘medieval foot’, was in use. That said, however, a recent survey of the limited 12th century piers still extant at Bordesley (1140-1150), and also on the more extensive chapter house façade mouldings of the Cistercian abbey at Coombe, Warwickshire (founded 1150), gave *feet* of 281 and 275 mm respectively, suggesting that at Bordesley, at least, the measures used for the layout and the mouldings were different. Greene lists data from Norton Priory which he claimed demonstrate that the ‘medieval foot’ (ie Roman *pes* of 296 mm) was more likely to have been used than the present statute foot of 304.6 mm.¹⁷ A ‘longer length’ analysis carried out on his quoted measurements, assuming integer *foot* values only, yielded a *foot* of 284 mm, suggesting that his may not be the case. There is, admittedly, scope for more investigation into these claims.

TWO CASE STUDIES.

The main work reported here has concentrated essentially on demonstrating the existence of the two measures, with little effort spent on interpretation. However, two examples are cited below where metrology has confirmed conclusions reached by other means.



Photo: Author

Fig. 9. Worcester crypt.

The layout and mouldings of the pillars in the Crypt of Worcester Cathedral were surveyed (Fig. 10). The spacing of the pillars was rectangular (1.734 x 1.589 m plinth edge to plinth edge). Regardless whether the spacing between the pillars was taken from centre-to-centre, or from plinth to plinth, the difference between the transverse and longitudinal lengths was 144 mm. Assuming this represented half a *foot*, giving a *foot* of 288 mm, then the separation distances between the plinths were five and a half and six *feet*. This value for the *foot* used in the layout compares with a *foot* of 337 mm for the mouldings.

This difference in *foot* values supports the conclusions of the late Philip Barker, who noted that many of the free-standing columns were damaged and worn, and that the mortar used for the present installation overlies this wear. He suggested that the pillars had been re-used from an earlier building, perhaps from the nearby St. Peter's church, the presbytery of which was enlarged in *c.* 1040 or later. On this basis, the pillars, which were constructed to the 'long foot' are earlier than the layout for which the 'shorter foot' was used.

The Basilica of Paray-le-Monial (France)

The splendid Burgundian Romanesque basilica of Paray-le-Monial, modelled on Cluny to which it was granted, now comprises a main church of the 12th century, described as 'Paray III', offset relative to an earlier 11th century narthex, dubbed 'Paray II'. Sample measurements from both areas yielded a *foot* of 336 mm for the narthex and chapel over (Paray II), and 284 for the nave (Paray III). These results are in line with those of Worcester where the longer foot was also in earlier use.

Whilst this and the Worcester example are perhaps mundane, it is encouraging that metrology can support, if not as yet generate, structural relationships.

The earlier use at Paray-le-Monial of the 'longer foot', to be followed by the 'shorter' may be compared with Prof. Kenneth Conant's comments regarding Cluny.¹⁹ He wrote "One suspects a new direction in the works from about 1075 onwards, because the 340 mm foot of Abbot Odilo's time was then given up in favour of the 295 mm Roman foot".²¹ Paray was a Cluniac house, founded in 999, and it too had a 'longer foot', superseded by a 'shorter' one.

There is, however, the proximity between Conant's 340 mm *foot* and 334 mm 'longer foot' presented here, and also between his 295 mm and the 280mm 'shorter foot'. Is it possible that his *foot* values were in fact 334 and 280 mm? Of course, it could be argued that the converse is true and that the values presented here should be as Conant gives them. Without Conant's evidence, this cannot be resolved, but the balance seems very much in favour of the values derived from the perch. Nevertheless, here again is the evidence of a 'longer foot' preceding a 'shorter', suggesting the relationship is time-based.

THE POST-NORMAN PERIOD

Changes in measure, even today, are embraced with neither enthusiasm nor alacrity (there are still pockets of resistance in Britain to the use of the metric system, introduced in 1965). It takes at least a generation to adjust, and it is suspected there would have been even more inertia following Richard I's Assize in 1198, despite iron measuring rods of the 'new' measure being despatched to all counties in England.

To track the decline of the 280 mm *foot*, and the advance of the present 304.8 mm foot, it was decided to take simple features common to both regimes, namely round and octagonal pillars found in church nave arcades. Some 200 have now been

recorded, in terms of diameters of the round pillars and ‘across the flats’ for the octagonal. The conclusions from this exercise can be summarised as:

1. Of the Norman pillars 88% were round and conformed acceptably to a 280mm *foot*.
2. Six nominally Norman churches used the 305 mm foot. These however, were all late with trumpet capitals and/or pointed arches, and might be deemed to have come within the influence of Richard I’s Assize of 1198.
3. In the post-Norman period, 57% of those measured, both round and octagonal, continued to use the 280mm *foot*, the remainder conforming to a 305 mm foot. The use of the 280 mm *foot* thus continued well into the 13th century.

CONCLUSIONS

Initially, it was shown by means of a ‘global plot’ derived from some 3,300 measured data that the ‘shorter foot’ of *c.* 280 mm was used in England in Norman times. Following this, a robust method of evaluating a *foot* value for individual sites was developed, and has now been used for the analysis of 68 English sites. As well as this ‘shorter foot’, there is evidence for a ‘longer foot’ of about 336 mm. The survey has been extended into mainland Europe, as windows of opportunity appeared, where similar results were obtained, with more emphasis on the ‘longer foot’, (Fig 11). It now evident that there is a system based on the perch or *pertica* of 5.03 m, one measure being one fifteenth of this, dubbed the ‘longer foot’ and the other one eighteenth, dubbed the ‘shorter *foot*’ giving values close to those experienced. The standard foot of 304.8 mm, confirmed at Richard I’s Assize of 1198, is an exact half-way compromise between the two. In the light of its apparently wide European use, the origins of the perch may well lie within the Roman system, it being equated to seventeen Roman *pes*.

An important key to the success of this entirely pragmatic approach has been the restriction the data to lengths not usually greater than a metre, and in many cases the *foot* value itself has been revealed. Longer lengths are more problematical, although some headway is being made on the assumption that only whole or half feet were used.

A recent development has been the finding of both perch-based units in the same buildings, the ‘longer foot’ being in earlier use for the two cases studies reported above.

COUNTRY	‘Shorter foot’ mm	No. of data	‘Longer foot’ mm	No. of data
England	278.8	1511	336.0	252
France `	277.3	1099	330.5	332
Spain	270.0	64	330.6	394
Sardinia	-	-	333.0	76
Mean/total	277.9*	2674	332.0*	1054
Derivation from 5.03m perch	279.4*		335.3*	
*Difference	0.54%		0.9%	

Fig. 11. Summary of mean *foot* values from Europe.

In contention with these findings, historical metrologists may flourish an array of alternative measures of values close to those found here, such as the *pied de roi* at

323 mm, derived as twelve-elevenths of a Roman foot, and another of 283.7 mm derived as twenty-fourth-twenty fifths of a Roman *pes*. Before these can be considered as serious contenders to those presented here, their viability needs to be established pragmatically.

It was noted in the text above that one cannot be too pedantic about the absolute values of the *feet* that have evolved, and therefore a method of reference to them is required. Clearly there is the 'longer' and the 'shorter foot' as used above, but these in themselves are insufficient to define them in the open field. As the discovery was made investigating Romanesque buildings, using the terms in the Sir Alfred Clapham sense of including Anglo-Saxon, it might be appropriate to refer to them as the 'Romanesque long' and the 'Romanesque short', but these titles may prove to be too restrictive.

Finally, it is recognised that this paper has left many questions unanswered, and by its nature is more of a progress statement than a definitive report. It is hoped that it might inspire students of architectural history to view metrology with more interest, and see it as a cultural masonic discipline, as well as a potential aid.

ACKNOWLEDGEMENTS

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2. Kidson, Peter, 'The Principles of Design', *Salisbury Cathedral*, (HMSO, 1993), 63.
3. Hirst, S. M. *et al*, *Bordesley Abbey II*, (BAR British Series III, 1983), 226 & Fig. 18.
4. Skinner, F.G., *A History of Technology*, Vol 1, (Clarendon Press 1954), 774.
5. Bagshaw, Steve, Archaeological recording at the south end of Gloucester Cathedral, 2000, (*Gloucester Cathedral Archaeological Report 2000/F, 2002*) 14.
6. Petrie, Sir W. Flinders, *Inductive Metrology or the Recovery of Ancient Measures*, (London, 1877), 3. His actual words were: 'Where a unit of measure has been lost to literature it can never be recovered by the use of present methods, since the only use hitherto made of the monuments has been to corroborate the known instead of discovering the unknown.'
7. Bettess, F, 'The Anglo-Saxon Foot: a computerised assessment', (*Medieval Archaeology*, Vol XXXV, 1991), 44-50. Having earlier developed a simpler version of his program, I was aware of the pitfalls of the method, and the possibility of it giving 'phantom' results. Working his data on my own program, I obtained a result of 335 mm, confirmed by the Ratio and Option analysis discussed in the Appendix below. Only eleven measurements were used to obtain his result, which I regard as too few. We have amicably discussed our differences. I now use my computer program only to look for ratios, when they are not obvious, and checking that a potential *foot* is not being missed.

8. Sunley, H, 'The Quest for the Linear Measure used in Norman England', (*Corpus of Romanesque Sculpture in England and Ireland*, News Letter No 15, October 2004), 3-5. The primary purpose of this note was to register my findings; the method of analysis outlined then has been developed and partially superseded.
9. Grierson, P, *English Linear Measures*, (The Stenton Lecture, 1971), 7.
10. Cocke, T and Kidson, P. (*Salisbury Cathedral, Perspectives on the Architectural History*, RCHME, 1993), 63.
11. Fernie, E.C., 'Anglo-Saxon Lengths: The 'Northern' System, the Perch and the Foot, (*Archaeological Journal*, 142 , 1985), 24
12. Huggins P. J, 'Excavation of Belgic and Romano-British farm with Middle Saxon cemetery and churches at Nazeingbury, Essex, 1975-76', (*Essex Archaeol. Hist.*, 10 1978), 29-117.
13. Rodwell, W.J. and K. A, *Rivenhall, : investigation of a villa, church, and village 1950-77*, (C.B.A. Research Rep., 1985), 55.
14. Of the three names, rod, pole or perch, the last is preferred. Its Latin name is *pertica* (which means a measuring rod) although several values of its length are ascribed to it. Some other writers prefer the term 'rod'.
15. Huggins P. J. Anglo-Saxon Building Measurements: Recent Results, (*Medieval Archaeology*, Vol XXXV, 1991), 21.
16. In the closing stage of this paper, I was contacted by Dr. David Cox who was preparing a paper on the Romanesque church at Evesham. In this he makes the point that the nave length is the same as at S. Etienne, Caen, and has derived, from this length, a *foot* of 332 mm. We are thus at variance, this perhaps emphasising the problem of dealing with longer lengths. At this late stage there is not the opportunity of resolving this.
17. Greene, Patrick, *Norton Priory*, (Cambridge University Press, 1989), 81.
18. Barker, Philip, *A Short Architectural History of Worcester Cathedral*, (Worcester Cathedral Publication: 2, 1994), 32. Worcester's first cathedral was dedicated to St Peter, and 'remained in use until at least the mid-eleventh century – after that nothing more is heard of it'. An earlier analysis of the present crypt suggested that the mouldings were to a foot of 270mm, but a more rigorous approach has now shown 338 mm to be the more likely value.
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APPENDIX

The Basic Analytical Methodology

The full analysis of the measurements at site level comprises four processes and two rules. This version of the analysis assumes a foot-type unit divided into twelve inches. For other potential systems, some revision of the details would be necessary. The terms associated with this methodology are indicated in bold type. The dimensions for the example of the process are taken from the responds of Binham Priory, Norfolk, for which the full procedure was required. The data and working are in centimetres:

1. **Data collection** consists of ranking all the measurements; ideally they will form a series of discrete groups, rather than a continuum. The **means** or averages of these groups and the numbers forming the groups, the **frequencies** are found..

EXAMPLE

The data were ranked in order, and arranged into discrete groups, A to J.

A 13.9, 14.0, 14.0, B 16.4, 17.0 C 19.0, 19.0, 19.0, 19.0, 19.0, 19.0, 19.3, 19.7, 19.8, 20.4, 20.5, 20.9, 21.0, 21.0, 21.1, 21.8, 21.8 22.0, 22.0, 22.0, 22.2, 22.5, 22.7, 22.8 D 24.0, 24.0, 24.5, 24.6 E 38.4, 38.7, 39.3, 39.5, 39.8, 41.1, 41.8, 42.0, 42.8, 43.0 F 62.0 G 68.0, 68.8 H 73.0, 74.5, 75.0, 75.0, 75.2, 76.1, 76.2, 76.6, 76.5, 76.8, 77.0 I 90.1, 92.0, J 120.5, 121.

The **means** of viable groups were then found (singletons eliminated), and their **frequency**, the number of data making up the group, are listed:

Ref	means	frequencies
A	14.0	3
B	16.7	2
C	20.7	24
D	24.3	4
E	40.8	10
G	68.3	2
H	75.6	11
I	91.0	2
J	120.7	2

2. **Ratio analysis** involves seeking within the **means** those that bear ratio relationships to each other, such as 2 to 1, 3 to 2 etc.. These are the **key dimensions**, the lowest member of which, the **basic unit**, is then used for **option analysis**.

EXAMPLE (Continued from above)

The **means** were now examined for ratio relationships. By simple inspection 20.7 and 40.8 were seen to be in the approximate ratio of one to two. However, it was decided to construct a **division matrix** by dividing each **mean** by the other, thus:

		D i v i d e n d								
		14.0	16.7	20.7	24.3	40.8	68.3	75.6	91.0	120.7
D	14.0	1	1.19	<u>1.49</u>	1.74	<u>2.91</u>	4.88	5.40	<u>6.50</u>	8.62
i	16.7		1	1.24	1.45	2.44	4.09	4.53	5.45	7.22
v	20.7			1	1.17	<u>1.97</u>	3.30	3.65	4.40	5.83
i	24.3				1	1.68	2.81	3.11	3.74	<u>4.96</u>
s	40.8					1	1.67	1.85	2.23	<u>2.96</u>
o	68.3						1	1.18	1.43	1.89
r	75.6							1	1.20	1.59
	91.0								1	1.33
	120.7									1

Here one is looking for integer or half integer relationships, but nothing lower. Clearly the strongest is a ratio relationship between 14, 20.7, 40.8 and 91, in the ratio of 1 to 1.5 to 3 to 6.5. The remaining relationships are pairs only and can be ignored (subsequent analysis showed that there was no overall trend relating them, and they were ignored).

The lowest member of the group, 14.0, now became the **basic unit** for **option analysis**.

3. **Option analysis** asks the question ‘what *inches* of what *feet* could the **basic unit** represent?’, and the possibilities are calculated. Candidates are eliminated using **Rule 1** which states that the *foot* sought will be within the

range of 25 and 35 cm. **Rule 2** states that the choice should lie with the option being a **regular** value, rather than a **stray value** of a *foot*. The **regular** parts of a foot are whole feet, halves, quarters and thirds (ie 3, 4, 6, 8, 9, or 12 *inches* etc.) and the **strays** are 1, 2, 5, 7, 10 and 11 inches and so on. In a random situation, the **regulars** and **strays** have equal chances of presence but the work reported above (Fig. 5) has indicated that the **regulars**, especially when **key dimensions** are involved, have a much higher presence. If after the elimination of candidates there is more than one option left, then the result is indeterminate. However, if a candidate from **option analysis** equates to one of the **means**, then this is a likely solution, but this was not the case here.

EXAMPLE (Cont.)

Option Analysis.

The answer to the question ‘what *inches* of what *feet* could the **basic** unit of 14 cm represent’ is calculated out as below:

Thus:

14 cm could be	4 <i>inches</i> of a <i>foot</i> of	42 cm (= 14 x 12/4)
	5	33.6
	6	28.0
	7	24

The first and the last were eliminated immediately because they are out of the range of a likely foot, **Rule 1**. The 5 *inch* solution is also eliminated by **Rule 2**, 5 *inches* being a **stray**, leaving a **provisional foot** of 28.0 cm.

- Final analysis** starts with inspecting all the **means** to see, now that an approximate *inch* or *foot* value has been determined, what other data can be accepted as being **regular** values of that *foot*. The **means** selected, which should represent the bulk of them, are then each divided by their respective foot values to give a **spot value** of the *foot*. The average of the **spot values**, weighted by their **frequency**, is determined (and a scientific calculator is best used for this), together with the **standard deviation**, a measure of the spread. The standard deviation is entered in an empirical **confidence table**, below, to determine the confidence band.

Confidence Table

<u>Std. Dev.cms</u>	<u>Band</u>	<u>Confidence</u>
0 – 0.3	A	good
0.3 – 0.6	B	fair
0.6 – 0.9	C	acceptable
greater than 0.9	D	poor

EXAMPLE (cont.)

The **means** and **frequencies** are listed, columns 1 & 2. The data are divided by the **provisional foot** value in column 3, giving approximate decimal values of the *foot*. These are rounded to the nearest **regular** decimal value ie 0.25, 0.33, 0.5, 0.66, 0.75 or zero, for full feet. These are the 'Regular values' values of column 4. The means of column 1 are now divided by the values in column 4 to give **spot values** of the *foot*.

1 means	2 freq.	3 mean/28.0	4 'Regular value'	5 columns 1/4 = Spot values
14.0	3	0.5	0.5	28.0
16.7	2	0.59	-	-
20.7	24	0.74	0.75	27.6
24.3	4	0.87	-	-
40.8	10	1.46	1.5	27.2
68.3	2	2.44	2.5	27.3
75.6	11	2.70	2.75	27.5
91.0	2	3.25	3.25	28.0
120.7	2	4.31	4.33	27.8

The Final Results

The **means** and **standard deviations** of the values in column 5 were calculated, taking into account the **frequencies** from column 2, resulting in the following:

FULL RESULTS

Foot value: 27.5 cm
Standard deviation: 0.21 cm,
Empirical confidence: band A, good
No of data used: 53
Data utilization : 90% (=55/61)
Breakdown of *inch* values (from column 4 above)
full feet: 0
half feet: 3
quarter feet: 3
thirds of feet: 1
other: 0
unidentified: 2