ARCHITECTURAL GEOMETRY

A Rare Geometrical Record from Rural Devon

Laurie Smith

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I went to the library and opened a book on
geometry for the layman.
I looked for the section on triangular surveying.
There was a diagram providing a simple explanation
of a method of surveying devised by people in ancient times.
This was the simplest way possible.
To find an object's height, measure its shadow at the very moment
when the length of the surveyor's own shadow equals his height.

The Guest Cat **Takashi Hiraide** PICADOR ISBN 978 1 4472 7940 2

Laurie Smith is an independent early-building design researcher, specialising in geometrical design systems. Because the medieval educational curriculum included geometry he uses geometrical analysis to excavate and recover the design systems of the past, a process he thinks of as design archaeology. He lectures, writes, runs practical workshops and publishes educational articles on geometrical design that are available as free downloads from his website

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For ease of reference
geometrical diagrams, photographs and combined photographs/drawings
are all listed in a single numerical order

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INTRODUCTION

A threshing barn was built at Hayne in Devon at an unknown time in the past but prior to the 1842 tithe map which recorded its presence. Built of cob on a stone plinth and with a thatched roof, the interior walls of the threshing barn were rendered with lime plaster to give a clean surface for the hygienic storage of produce. As the plaster set it was divider-scribed with an extensive array of geometrical symbols that included the daisy wheel shown in the photograph above. The hand gives a sense of scale.

The text on the following pages describes how a change of ownership at Hayne led to the discovery of this exceptional collection of geometrical symbols. It describes how the symbols were scribed geometrically with dividers, how they can be used to generate further constructions and how their symmetry and proportions can be used to design the footprints and sections of buildings, including those of the barn itself.

The use of identical symbols, found in countless historic buildings from houses and barns to churches and cathedrals, reveals the Hayne symbols as part of a countrywide proportional design language that informed the work of carpenters, masons and other craftspeople employed in the design and construction of buildings.

The lay of the land

The county of Devon encompasses two great moors: Exmoor, which overlooks the Bristol Channel along the county's northern coast and Dartmoor, close to the English Channel in the south. Prevailing south westerly weather from the Atlantic saturates both moors with rain to swell the mossy reservoirs that feed the county's rivers. The rivers run from the moors to the sea but in a paradoxical way with many of those from Exmoor in the north flowing down to the south coast and a good number from Dartmoor in the south flowing up to the north coast. Between the north flowing Taw and south flowing Exe an extensive, undulating patchwork of farmland is watered by their countless tributaries. One of these, the river Mole, gives its name in passing to the village of North Molton and town of South Molton as it flows south. Hayne is further south again, hidden from view in a shallow valley[1].

Rise and fall

In its heyday, around 1900, Hayne was a prosperous farm. The farmhouse front windows, overlooked a farmyard comprising a threshing barn, with an east west threshing floor for the prevailing westerly wind to winnow chaff from grain, an adjacent timber granary, an open fronted stone barn for carts and horses, a range of pigsties, an orchard and round house cider press, all surrounded by arable and grazing land. But, as the years moved towards the first World War, fate passed a grey cloud shadow over Hayne's green fields and blew bitter winds through its family tree until the bright leaves withered and fell to earth. The traumatic aftermath of the first world war, the deceptive sanctuary of alcohol and the cruel loss of a young child, killed by a falling stone from the round house wall, brought the farm to its knees. Neglect followed, thatch was left to rot, let in rain and the saturated cob walls began to collapse. The house was demolished and there were debts to be paid so fields, produce and stock were sold. When bailiffs called to collect chattels from the property, the family threw their furniture in the duckpond and filled it in. A hundred years later, in 2000, what was left went on the market.

The Editor, the Photographer and the Geometer

The new owner was Richard Westcott, editor of *The Three Hares, A Curiosity Worth Regarding*[2], a deeply researched book that explored the origin, meaning and international distribution of the enigmatic three hares symbol. The book's photographs, taken by the Dartmoor photographer Chris Chapman, included an image of a three hares roof boss from the church at Corfe Mullen in Dorset. When I analysed the Corfe Mullen boss I had discovered the precision geometry of its layout and my drawings were incorporated in a joint contribution by Richard and myself in the book's final chapter. Conversations followed about the three hares and the compass drawn daisy wheel at its geometrical source, and it was during one of these exchanges that Chris remarked that Richard had a daisy wheel in his barn. Half an hour later we were leaving the tarmac lane behind and following a narrow track down through the sloping fields to Hayne, on our way to see Richard's daisy wheel.

1

2

Photograph 1 shows Hayne farmhouse circa 1900. The dwelling is lime washed and the barn extension to the left is raw cob, with both sharing a thatched roof. The narrow front garden is protected by a substantial stone wall with a horse mounting block beside the entrance gate. The elegant ladies, whose names are unknown, are dressed in their best, holding their poses in daylight for the long exposure necessary for the plate cameras of the time. Photograph 2 shows Hayne at the centre of its fields from an 1842 tithe map. The house (tinted pink) and the pigsties were demolished. The threshing barn and the small wooden granary survived.

First sight

It was a beautiful summer afternoon with the sun high in an azure sky above luminous fields as we approached the threshing barn. We could see Richard's repairs. Four stout timber buttresses supported the outward leaning cob east wall. All four external walls, from the original stone plinth to the eaves were re-rendered and limewashed and a new but traditional corrugated iron roof kept the building dry. The light was so intense outside that, apart from the doorway, the barn's interior seemed deep in shadow as Richard began to look for the daisy wheel on the inside of the buttressed wall. At first we could see nothing but then, as our eyes slowly accustomed to the gloom, the daisy wheels gradually appeared. They shared the wall with an array of circular geometrical constructions, some complete, some incomplete, some drawn across the face of others, some difficult to detect, all inscribed at a variety of scales into the wall's lime plastered surface. When we illuminated the walls with torches we found more and more constructions, in fact I had never seen so many in one place. Tracing a finger along their curvilinear tracks was like entering a labyrinth of braille geometry. Photograph 3 shows the threshing barn's buttressed east wall and photograph 4 shows a divider-scribed daisy wheel from the wall's inner surface.

3

4

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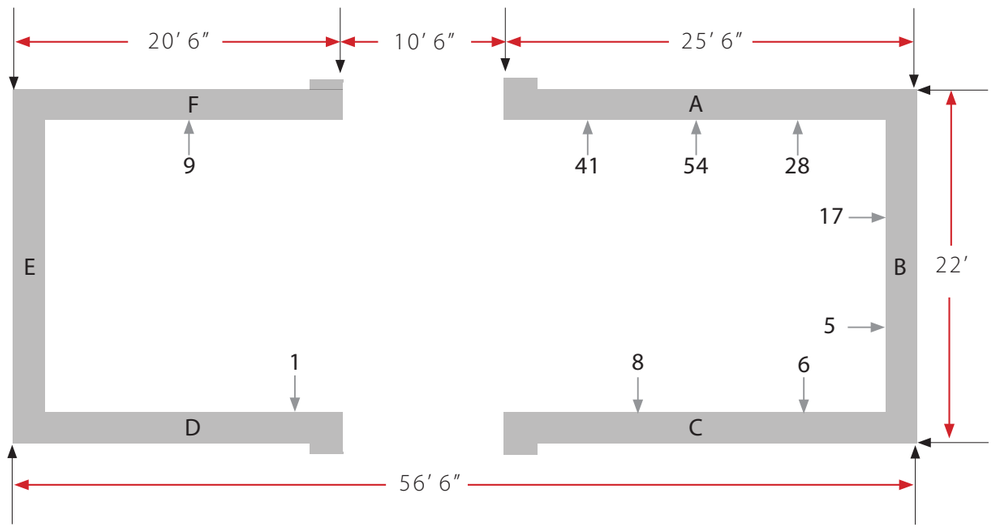
Enigma and questions

The discovery of so many daisy wheels and other compass geometries on the inside of the buttressed wall was initially overwhelming. It wasn't quite the discovery of a coin hoard but it was numerically significant enough to raise some questions that needed answers. The first was whether there were more geometrical symbols on the remaining walls and a quick torchlight search revealed that every wall except the north gable, which appeared to have been replastered, had further geometrical symbols. Why were there so many and how many were there in total? We decided to count them but needed to work out how best to do so. When were they scribed and who might have scribed them? What tools were used to scribe them and who might use these tools? What was their function, if any? Why geometry and what was it doing on the interior of a remote barn in the Devon countryside?

Counting the symbols

By coincidence we had the right team to research our questions and seek some answers to them. Richard owned the barn, was excited to learn more about the symbols on his walls and gave willing access to them. Chris had all the photographic skills and technical equipment to record the symbols. I had the geometrical understanding, knew how to draw the symbols and how to interpret their meaning. Our first decision was to measure the barn's footprint, divide the walls into sectors and count the symbols but this was easier said than done. They were so numerous that they were difficult to count with accuracy because many were visually elusive among the barn's accumulated dust, gossamer generations of spiders' webs and plaster damage from farm work. We gently swept the walls to reveal the symbols, photographed each sector, magnified the scale on computer, adjusted exposure settings to reveal symbols that were invisible at smaller scales, superimposed a grid of lettered and numbered squares, circled each symbol to locate its position and, finally, counted the rings. Drawing 5[3] shows the barn's measured footprint, the alphabetic labelling of the walls and the locations of the groups of symbols, the greatest number, 123, appearing on the buttressed Wall A.

5



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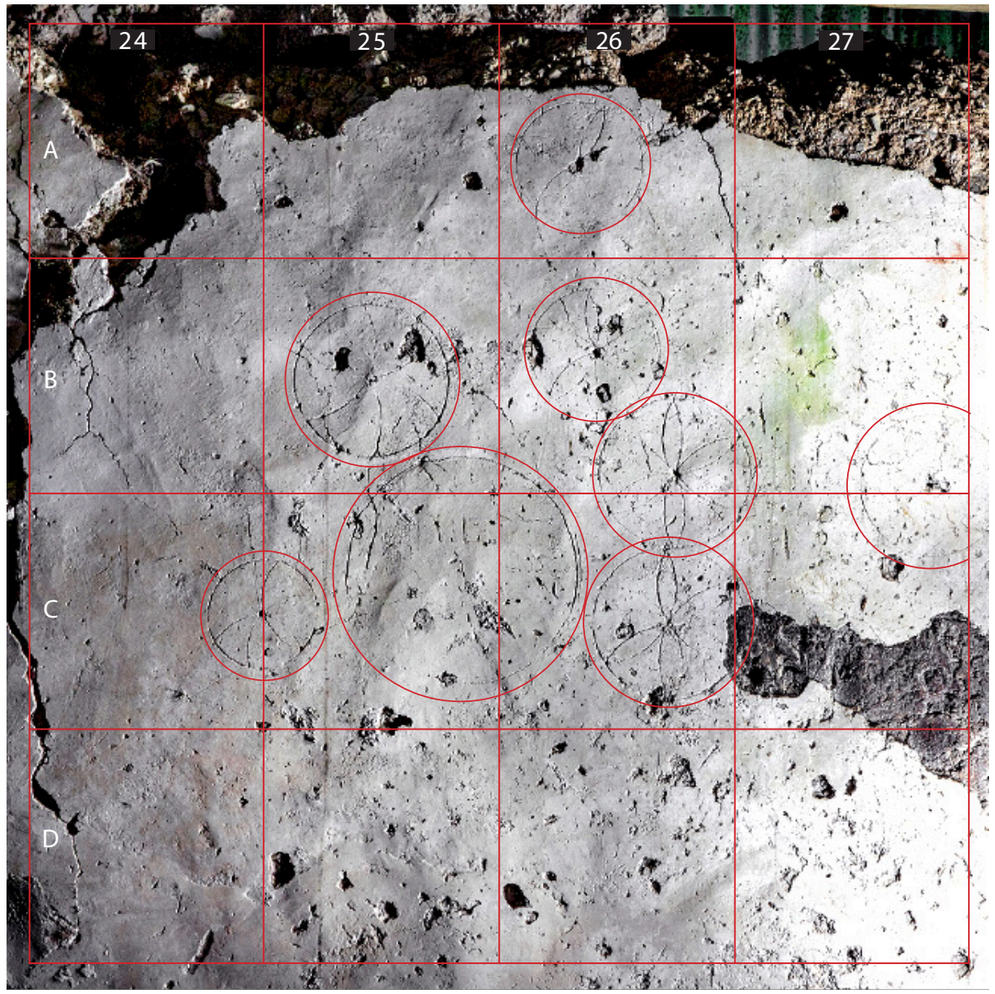

Drawing and photograph 6 shows a gridded section of Wall C with a count of 8 symbols. Six are daisy wheels, three of which have an identical radius and were almost certainly scribed with the same dividers. The photograph reveals the presence of the cob wall beneath the plaster as well as fracturing of the cob, to the left of the image, that has broken the plaster surface. Along the top of the wall the plaster has been lost from the cob as if cracked and removed like eggshell from a boiled egg. The whole wall is peppered with small scale damage but this post dates the symbols which were scribed just after the plaster was freshly applied and had begun to set. The setting time for lime plasters was long compared with modern gypsum plasters and was conditioned by a number of factors. The plaster's intrinsic setting time was modified by the weather, it would set more slowly in wet weather and more rapidly in hot, dry weather but its setting time was also influenced by the body of the wall beneath it. Plaster applied to a newly built cob wall would set more slowly if the cob still retained some of its own moisture but would dry far more rapidly on dry, porous walls that absorbed moisture from the plaster. Plaster thickness was a factor, thick drying slowly and thin drying fast.

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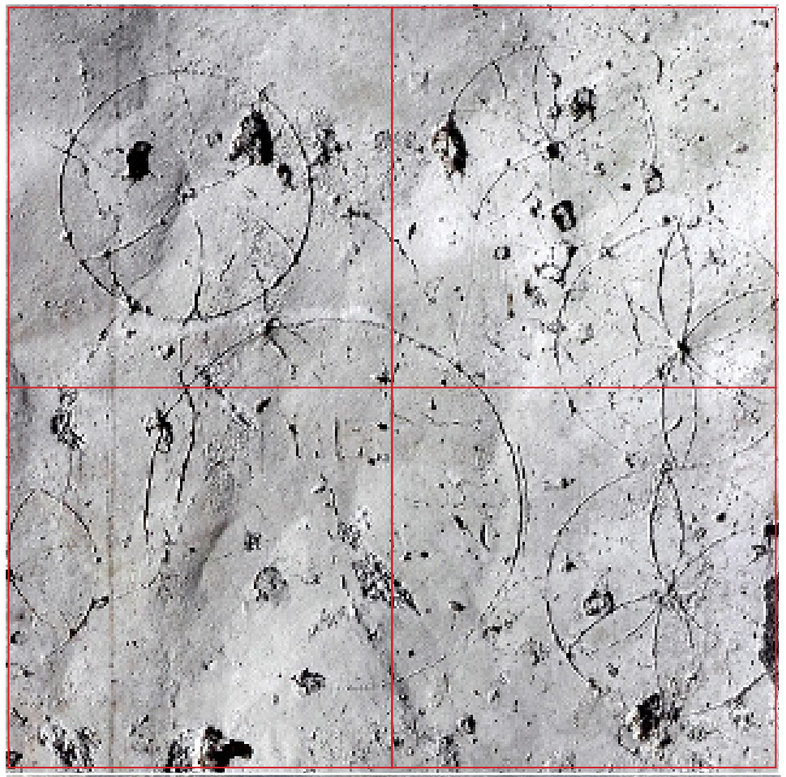
7



8

Photograph 7, which enlarges the four central squares of drawing 6, shows the character of the scribed symbols. The daisy wheel, top left, and the two daisy wheels on the right, are all scribed accurately on a vertical axis and were clearly scribed by someone with geometrical knowledge.

Photograph 8 shows the type of dividers used to scribe the geometrical symbols. The divider's lower arm and the curved support are fixed to each other while the upper arm, which is free to swing through a range of angles along the curve, can be locked into place by a butterfly screw. These dividers are large, the lower arm being 16½ inches in length, exactly one twelfth of a medieval Rod, Pole or Perch (see Rod, Pole and Perch on page 28).

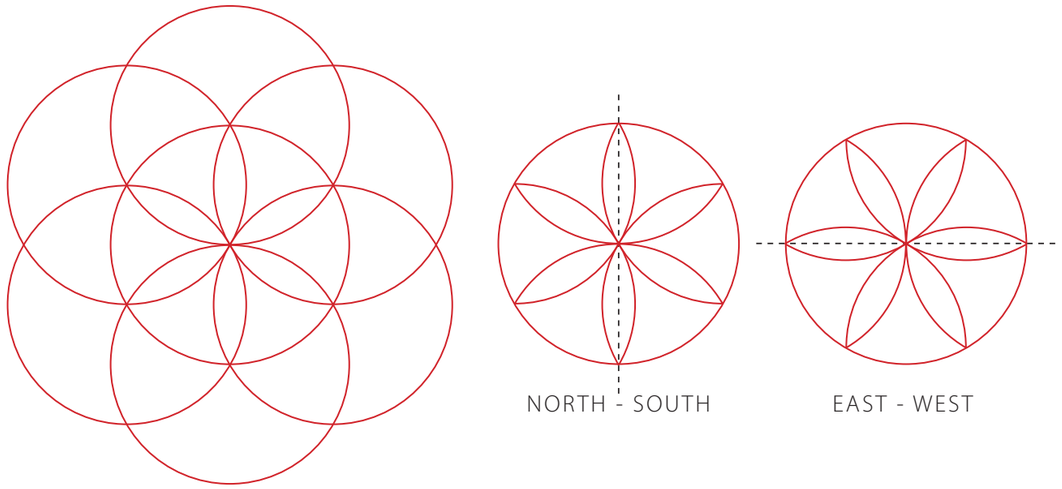
IDENTIFYING THE RANGE OF SYMBOLS

The Daisy Wheel

Viewing photographs of the 169 symbols revealed a varied assortment of circle-based geometrical constructions on a variety of scales and the first task was to identify examples of each. The dominant geometry was the classic six-petalled daisy wheel that most people have drawn at school. The wheel can be scribed with either a north-south axis, an east-west axis or at an abitrary orientation. Daisy wheels could be scribed either as complete geometries or with arcs missing from their interior. Examples of all of these can be found on the barn's walls. Drawing 9, left, shows the full construction of the daisy wheel from a ring of six circles, drawn consecutively around the circumference of the primary or central circle, which automatically form the six petalled flower at the symbol's centre. The full construction, left, is not evident on the barn's walls but is shown here as the geometrical source of the simpler wheels which show only the central flower. These are shown below in drawing 9, right, and photographs 11 and 12.

A development from the daisy wheel is the double daisy wheel where a north-south wheel and east-west wheel share the same axis and circumference. The second wheel is drawn from a point exactly half way between two of the first wheel's adjacent petal tips. Locating the half way point is shown in drawing 10, left. The combined wheels are shown in two colours in drawing 10, right, and in photograph 13. The double wheel is scribed on Wall F.

9



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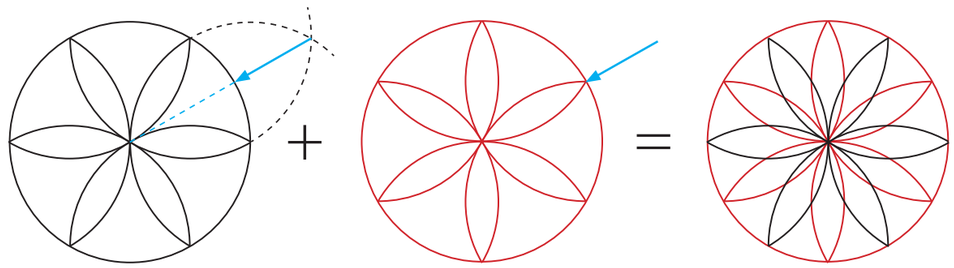

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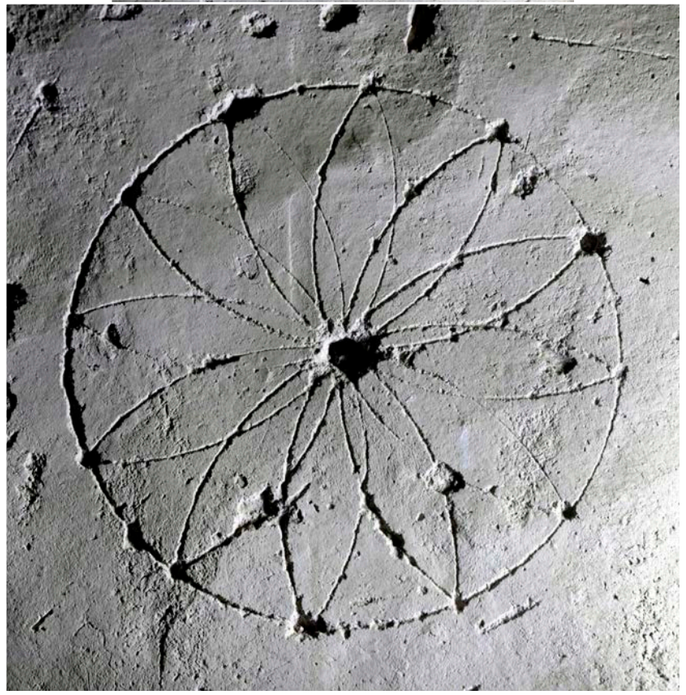

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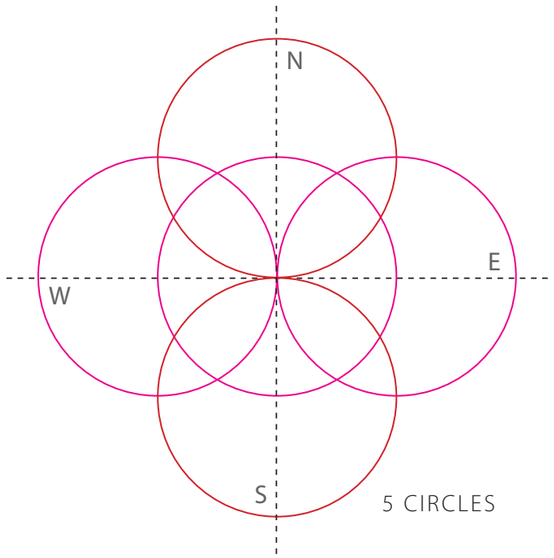
5 Circle Geometry

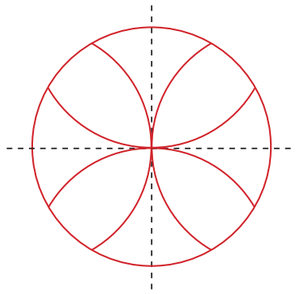
There are several examples of 5 circle geometry on Wall A. Like the daisy wheel, the construction begins with a primary or central circle that can be drawn on either a north-south or an east-west orientation. Unlike the daisy wheel, the two orientations are combined in a single construction so that they intersect at the axis of the primary circle. The circumference is therefore cut at its north, east, south and west poles. Four further circles are drawn from the four poles so that they kiss at the axis of the primary circle. All four polar circles and the primary circle are drawn to the same radius. The 5 circle geometry can be drawn either as a full construction, drawing 14, or as a shorthand version where the four polar circle arcs terminate at the primary circle's circumference, drawing 15. Keeping the eye on drawing 14 it can be seen that the construction incorporates both horizontal and vertical chains of three circles but, because the central circles of each chain overlap, the configuration appears as a 5 circle construction.

14



5 CIRCLES

15



SHORTHAND

Photograph 16 shows a full 5 circle geometry scribed high on the wall at wall plate level. The arctic element of the north circle has been lost due to the plaster being damaged at an unknown time in the past. The symbol is drawn on a slight variation from true vertical and horizontal orientation as shown by the superimposed black centre line. The black arrow marks the axis of the primary circle and the red arrows mark its circumference. The red arrows are simultaneously the axes of the east and west circles. The east and west circle circumferences kiss at the primary circle's axis and their diameters extend as far as the blue arrows.

To the right of the full geometry in photograph 16 there is a scribed shorthand version of 5 circle geometry overdrawn in red line. This symbol is shown enlarged in photograph 18. All of the actual circles in photographs 16 and 17 are clearly scribed to the same radius, possibly by the same hand.

16

17

18

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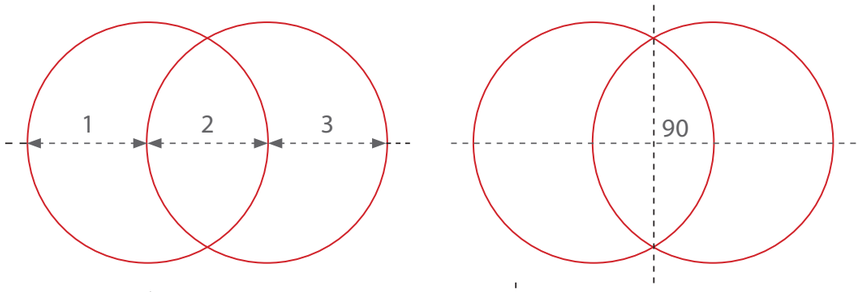
4 Circle Chain

In a 4 circle chain each successive circle is drawn from its neighbouring circle's circumference along a centre line that acts as a guide for the divider pin as each circle is drawn to the same radius. The simplest chain, of 2 circles, generates three sectors, two identical but in mirror image at opposite ends of the construction and a distinctive central shape known as the Vesica Piscis. The Latin words Vesica Piscis literally mean fish's bladder, fish (piscis) from its shape and bladder (vesica) in the sense of an inflated sac[4]. The vesica can be found in ecclesiastical architectural sculpture as an aureole surrounding the figure of Christ. Drawing 19 shows the vesica's construction along a centre line with dividers set to a single radius, automatically dividing the line into equal lengths, left, while bisecting the vesica generates a 90° right angle.

Drawing 20, lower left, is constructed on a vertical centre line and, lower right, shows how the points where circles intersect can be linked across the chain to generate a series of equal horizontal divisions. Each circle contains arcs found in both the daisy wheel and 5 circle constructions with those in the bottom circle emphasised in black. The drawing, on the far right, shows a divider-scribed cusped line derived from the 4 Circle Chain.

19



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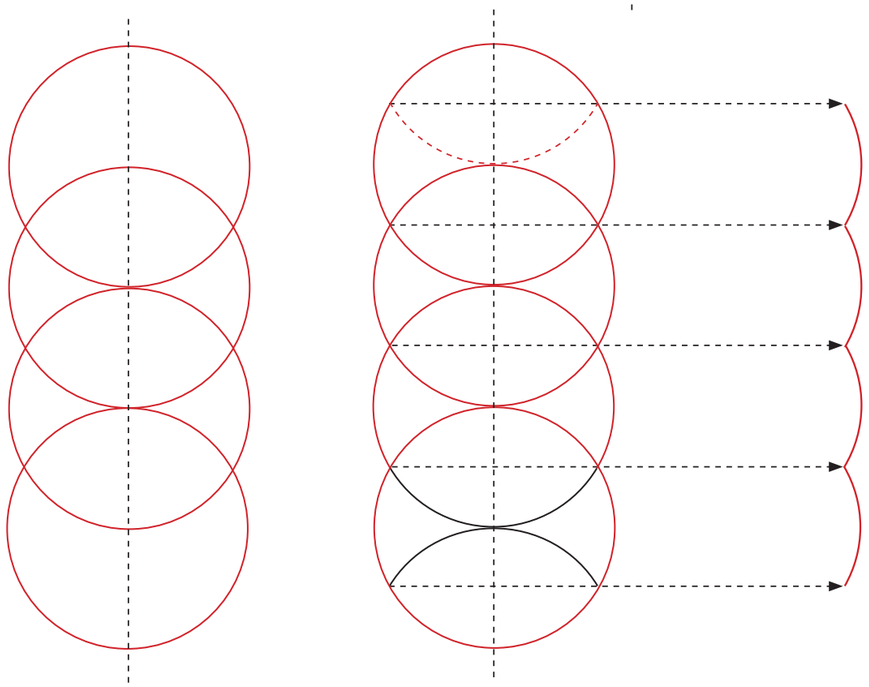

21

Photograph 21 shows a scribed vertical 4 Circle Chain. Scribing a vertical chain requires consideration and preparation and is best done by scribing each succesive circle from a vertical centre line at the precise points of intersection where each circle cuts the line. However, there is no sign of a scribed centre line on the wall so the more likely scribing method was to step each consecutive circle axis down either a vertical chalkline, plumbline or the edge of a straight lathe and then scribe from the marks. The circles are in almost perfect vertical alignment, the two central circle axes being fractionally to the left of the centre line.

22

Cusped Lines

Photograph 22 shows a scribed cusped line with each consecutive arc scribed from a point triangulated from its ends as shown by the superimposed triangle and the dividers. It can be seen that the *idea* of the cusped line comes from consecutive sectors of a circle chain, see drawing 20, and that each completed arc acts as the start of the next, from points B to E.

The angled linear scratches at the photograph's lower right have no geometrical meaning but are possibly tally marks recording storage in the barn.

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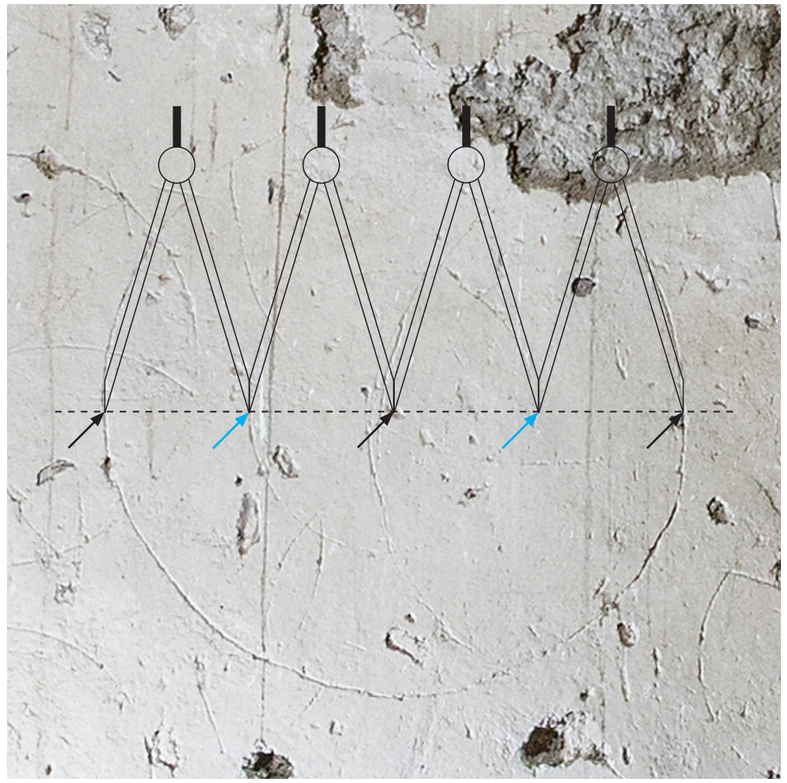
23



Concentric Circles

Concentric circles are always drawn from a single centre so that each successive circle is absolutely parallel to those preceding it, a process that is simple to attain with a compass or dividers. Concentrics can be drawn inside the primary circle, outside it or both.

Drawing 23 shows two concentric circles, the smaller of which is delicately scribed and visually faint. The large outer circle has its axis at the central black arrow and its circumference passes through the two outer black arrows. The small inner circle shares the large outer circle's axis and its circumference passes through the two blue arrows. Dividers stepped along the centre line show that the large circle's diameter (4 steps) is exactly double the small circle's diameter (2 steps). Alternatively, the small circle's diameter is exactly half that of the large circle. Halving and doubling are important geometrical characteristics that are found most commonly in the relationship between the radius and diameter of a circle where, on a centre line, two radii equal one diameter (see Rod, Pole and Perch).

The two concentric circles in photograph 23 are very simple and accurate in construction but there are further, more complex, concentric circles scribed into the barn's plaster; some of which are based on the daisy wheel and others on 5 circle geometry. These are shown and described below.

THE HISTORICAL USE of the DAISY WHEEL, 5 CIRCLE GEOMETRY and CIRCLE CHAINS

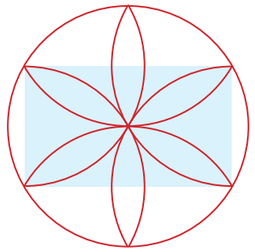
The three geometries described on the previous pages, the Daisy Wheel, 5 Circle Geometry and the 4 Circle Chain share identical elements of construction, when drawn to the same radius, and therefore also have proportional characteristics in common. All three geometries have been recorded in historic timber framed and masonry buildings, so looking at examples of their historic use might throw some light on how and why so many came to be scribed on the threshing barn's walls.

Daisy Wheel Design
Saint Andrews Church, Sutcombe, Devon, Thuborough aisle

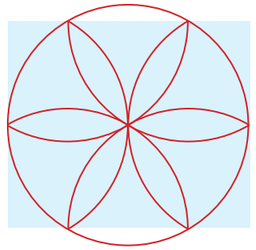
The first example is a daisy wheel from my home village. It is found on a carefully lettered datestone on the western gable of the Thuborough aisle of Saint Andrews Church, Sutcombe, a Grade II* listed building. The datestone faces towards the church lychgate and is clearly visible to approaching churchgoers, just as they reach the entrance to the porch. The datestone, which is surrounded by a rectangular cartouche[5], records IB 163O RB and it is the O that is of interest here because, unlike the fluid lettering of the remainder of the inscription, it is a geometrically perfect circle and has a daisy wheel at its centre, photograph 24. What does it mean?

There is no record of who IB and RB were. Perhaps they were church wardens, benefactors or maybe the masons who built the chapel. My view favours the masons because masons and carpenters used geometrical systems to design the footprints and sections of buildings. The daisy wheel is the source of two important rectangles, the 4 point rectangle and 6 Point rectangle, shown in drawing 25, which are used as proportional guides for floors, doors, windows and small details like lock boxes. As the names suggest the rectangles are formed by linking either four or six of the petal tips on the daisy wheel's circumference. The 6 point rectangle is twice the area of the 4 point rectangle.

24

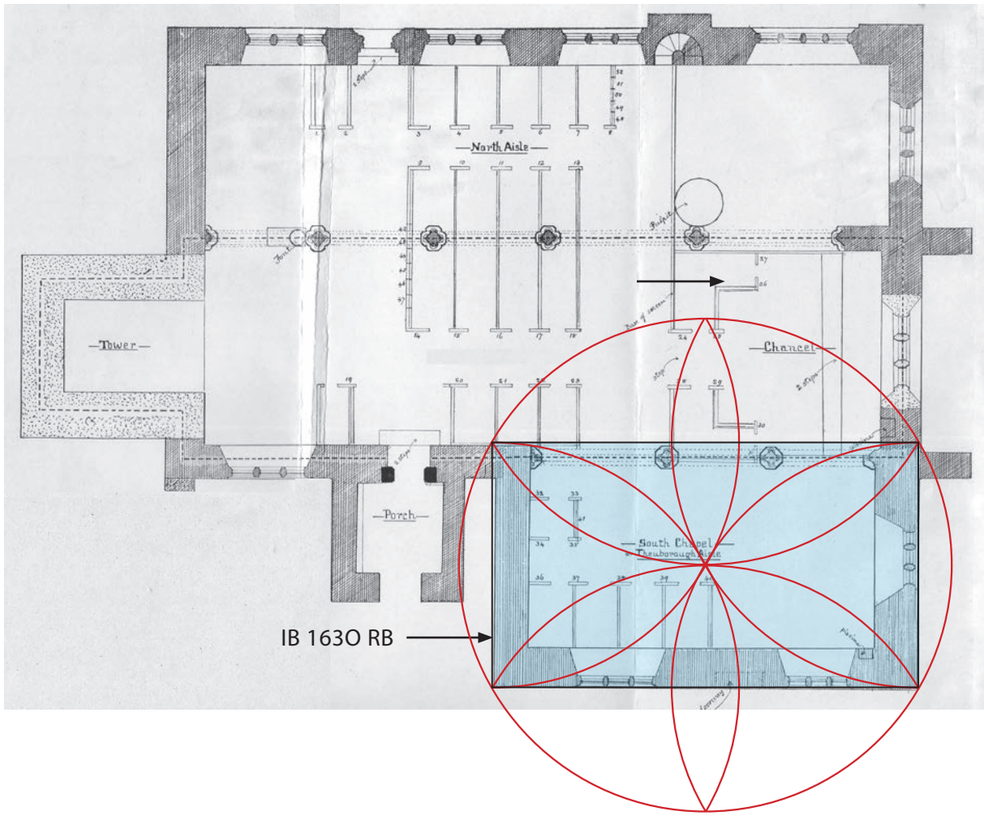


4 POINT RECTANGLE



6 POINT RECTANGLE

25

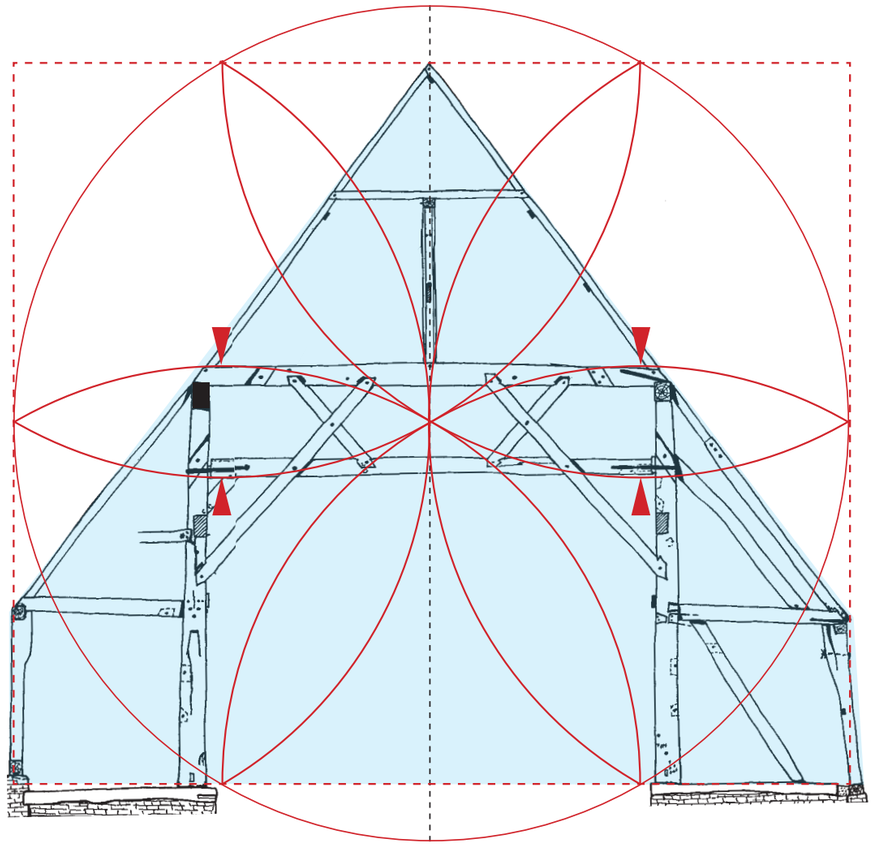


The daisy wheel was a commonly used design geometry and is scribed into hundreds if not thousands of timber framed buildings. Knowing this from years of research into historic building design encouraged me to look at the measured floor plan of Saint Andrews Church, diagram 25. The Thuborough aisle is tinted blue with a daisy wheel suprimposed upon it and it is precisely a 4 Point rectangle. The black arrow shows the datestone's location, close to the porch entrance. The aisle footprint is 33 feet long by 19 feet wide (see Rod, Pole and Perch), exactly the dimensions of Ernest Shackleton's Nimrod Hut, built to his own design specifications for the Antarctic Expedition of 1907, 277 years after the construction of Sutcombe's Thuborough aisle.

Daisy Wheel design
The Barley Barn, Cressing Temple, Essex

The Barley Barn was built by the Knights Templar at Cressing Temple in Essex in 1220 AD and the Wheat Barn, adjacent at right angles to it, in 1260 AD. The two barns are the largest and most complete medieval barns in Europe. The Barley Barn is aisled either side of a central nave and is 49 feet 6 inches or 3 Rods in width (see Rod, Pole and Perch). The barn's carpentry predates the English tying joint, which connects a building's corner post, tie beam and wall plate in a single joint. The pre-tying joint solution was to place double tie beams across the two threshing bay trusses. The lower tie beam connected the aisle posts by slip tenons and held them steady while first, the arcade plate, and then the upper tie beam were placed and pegged.

The Barley Barn section is designed within a 6 point rectangle that passes through all six daisy wheel petal tips. The distinctive double tie beam is determined by the maximum depth of the wheel's horizontal petals at the red arrows, which mark the upper face of the upper tie beam and lower face of the lower tie beam in drawing 26. Drawings 27, 28 and 29 show the geometrical points of intersection and linked alignments that complete the frame design. Diagonals between opposite corners of the rectangle and the wheel's petal tips in drawing 29 define the distinctive X braces between the double tie beams (see also drawing 26).



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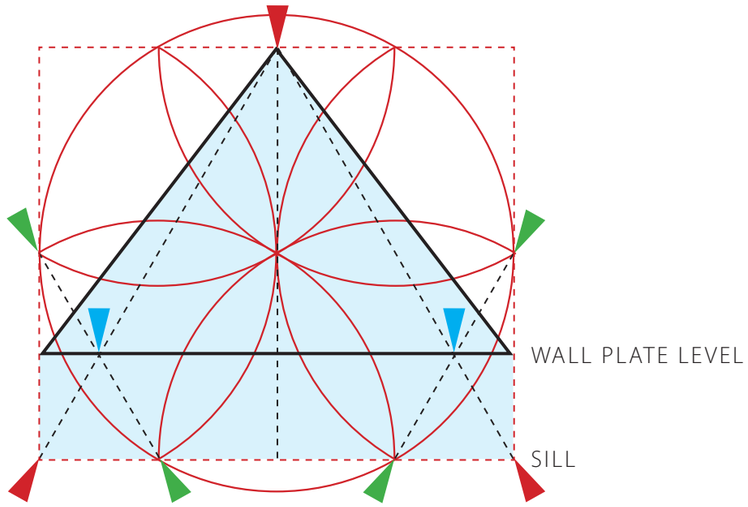

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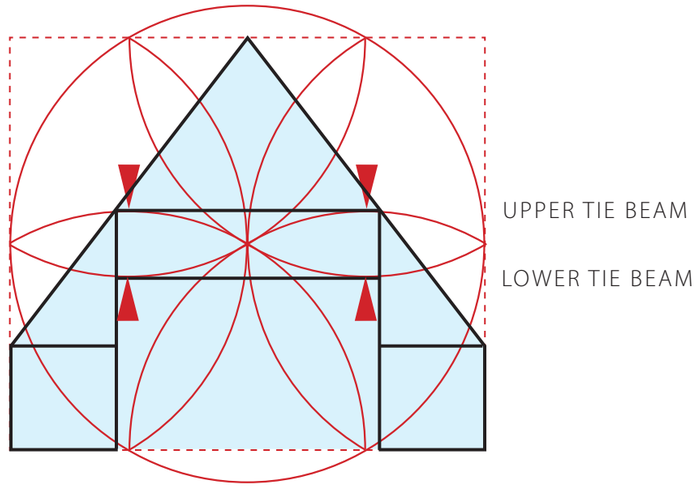

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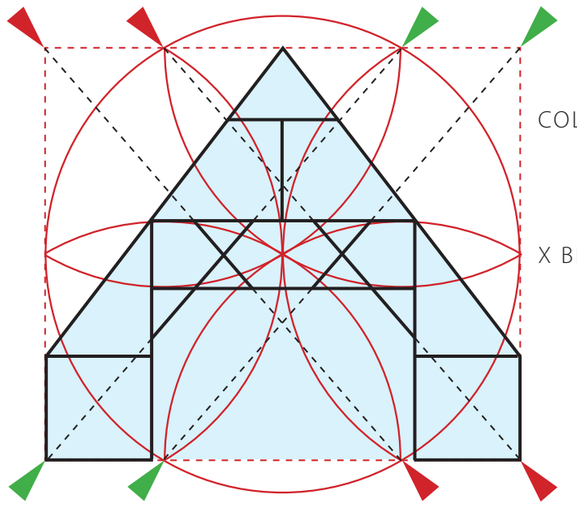

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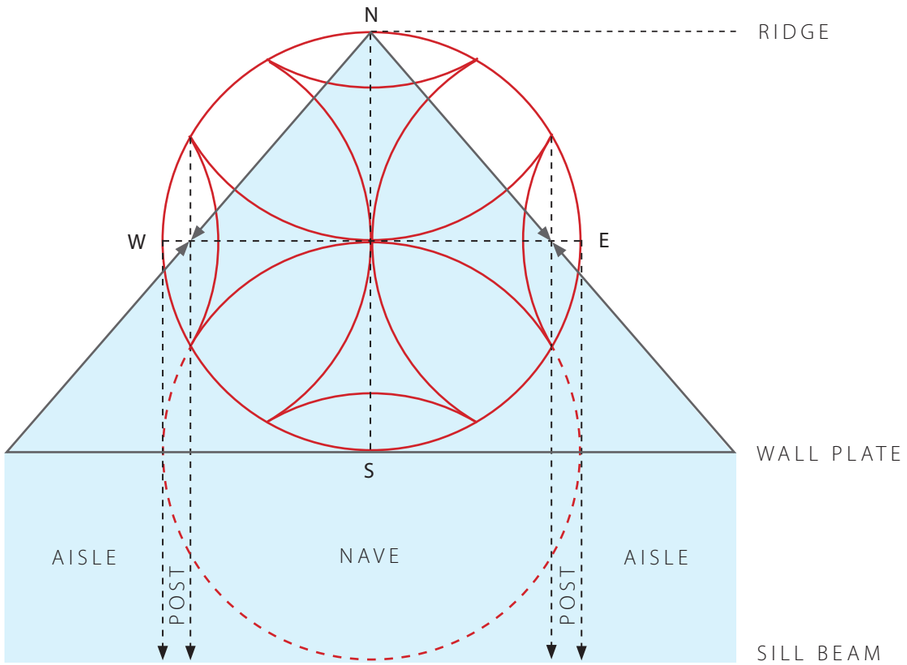
30

CLWYD POWIS ARCHAEOLOGICAL TRUST

5 Circle Geometry building section design
Tŷ Mawr, Castle Caereinion, Montgomeryshire[6]

Tŷ Mawr is a Welsh timber framed aisled hall, dendrochronologically dated to 1460. Rediscovered after total dereliction, the house was recorded and eventually repaired in 2000AD. During recording a geometrical symbol was discovered race-knifed into an aisle post in the building's north gable, video still 30, above. Noticeably, the symbol's 5 circle geometry has four extra short arcs linking the ends of the long arcs adjacent to the north, east, south and west poles. The short arcs are scribed to the same radius as the main 5 circle geometry. Drawing 31 shows how the roof pitch is triangulated from the symbol with the ridge and wall plate governed by the primary circle's north and south poles while the angle of pitch passes throughthe bisected centres of the east and west polar vesicas. and how the ridge and wall plate are governed by the north and south poles. Extending the symbol's southern long arc into a full (dashed) circle gives the building's sill beam level. The full building section, from sill to ridge, is shown in blue tone.

31



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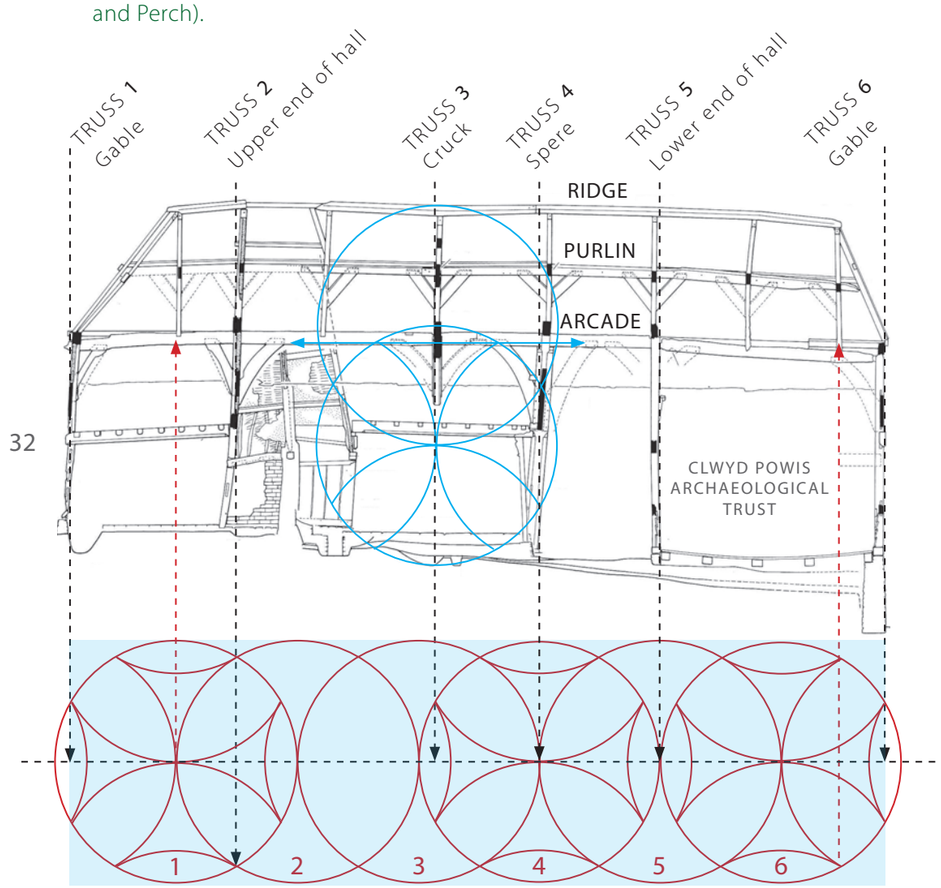
6 Circle Chain nave floor plan and long section design
Tŷ Mawr, Castle Caereinion, Montgomeryshire

Tŷ Mawr is a linear building and its floor plan commences with a chain of six interwoven circles set out along a centre line with all six circles drawn to an identical radius. The 6 circle chain and the area of the footprint, in blue tone, are shown in the lower section of drawing 32. Once the chain is drawn, further geometrical constructions can be made within the circles, specifically the 5 circle geometry shown in the end circles of the chain, and alignments can be drawn through the chain (shown previously in drawing 22).Tangents to the six circles and perpendiculars drawn through the terminal vesicas determine Tŷ Mawr's nave footprint.

The upper section of drawing 32 shows how alignments taken from cardinal arrowed points within the chain can be projected as the gables and cross walls of the house. It also shows how the house is 1½ circles in height and how the 5 circle geometry's internal arcs and circumference in the lower circle generate the curvatures of the arcade plate braces and the horizontal level of the arcade plate.

Whether drawn on the level as a nave geometry or vertically as the height of the long section, the diameter of all circles is 16½ feet or 1 Rod (see Rod, Pole and Perch).

32



33

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FITTING THE JIGSAW TOGETHER

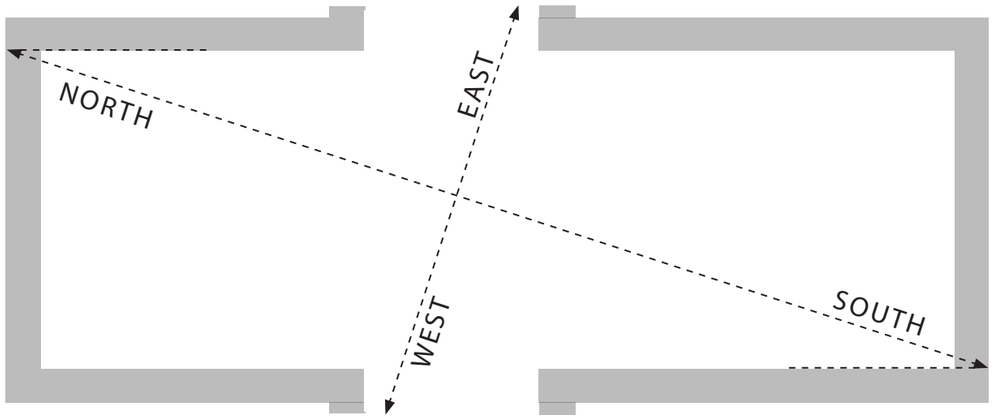
The threshing barn

Photograph 33 shows Laurie Smith, left, and Richard Westcott, the barn's owner, standing adjacent to the threshing floor with daylight entering from the east facing door. The photograph was taken through the barn's southern gable pitching window by Chris Chapman, perched on an external ladder in the rain. The box fixed to the tie beam is home to the resident barn owl, a descendant of those who historically kept the barn clear of vermin. The trusses are simple A-frames with overlapped rafters providing V housings for the diamond set ridge beam and tie beams half way up the roof plane. The rafters are set on horizontal wall plates that spread the roof load along the top of the long cob side walls. It is noticeable that tie beams along the west wall, left, have had later, vertical supports added.

In the beginning

The barn is sited on a precision orientation with its long diagonal running north-south, exactly the same as the Grade 1 listed Harmondsworth Great Barn, adjacent to Heathrow Airport, London. The threshing floor is oriented east-west and Chris commented that when it was in use with the doors open at either side, the west country's prevailing westerly winds would blow the light chaff from the heavier grain and out through the east door. How was the diagonal attained and the barn's footprint set out on the ground?

34



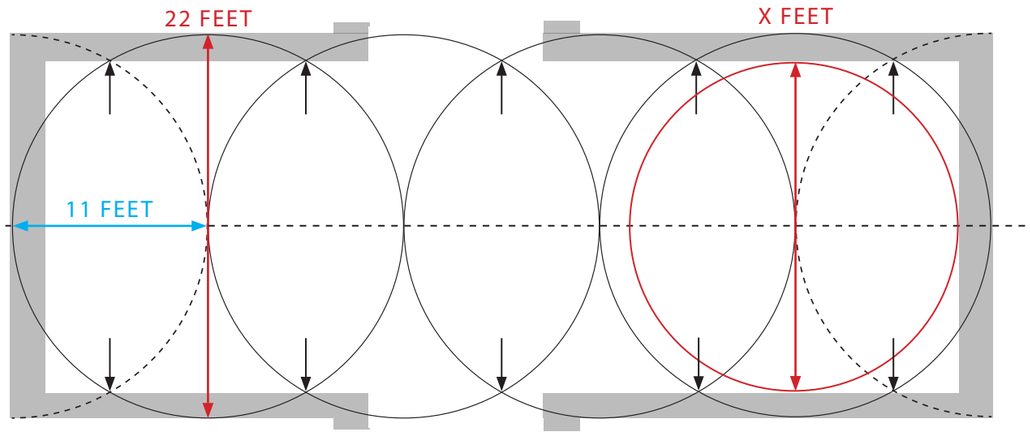
Establishing a north-south orientation could be achieved by visual observation of sunrise in the east and sunset in the west, plotting the orientation on the ground and then setting out the north-south orientation at right angles to it. Alternatively, a magnetic compass would give the cardinal directions. However, once the north-south orientation was marked out along the ground as a taut line between pegs, the next issue was to calculate where the barn's footprint would stand in relation to it. For this it was essential to have a design for the barn so that the true length of the diagonal could be defined on the ground and the angles between the diagonal and gable walls correctly set out. There were simple geometrical ways of carrying this out.

Designing the barn footprint

The historic building examples and their underlying geometrical design systems shown on the previous pages raise the possibility that the barn might be designed in a similar way with reference to identical symbols divider scribed into its lime plastered walls. The logical starting point is with a circle chain, the symbol shown in photograph 23, which is similar to the 6 circle chain that defines the aisled hall nave at Tŷ Mawr in Wales.

Circle chains enable a standard radius or diameter to be stepped out (see Stepping Out) along a centre line and because the barn, as built, has a width of 22 feet, a chain of circles can be drawn to 22 feet diameter or 11 feet radius. This is easy to superimpose upon the measured drawing of the barn's footprint but before the barn existed a scale drawing would have been a necessary reference. Because Imperial dimensions were in use at the time the drawing would have been in feet and inches. With 12 inches to an Imperial foot it follows that a circle drawn to 11 inch radius at 1:12 scale is 11 feet radius at full scale. A 4 circle chain drawn to 11 inch radius would be 55 inches, almost 5 feet in length. A chain drawn at half that scale, 1:24 at 5½ inches radius, would be 27½ inches in length, a more practical drawing size at just over 2 feet in length, similar in scale to a modern drawing board.

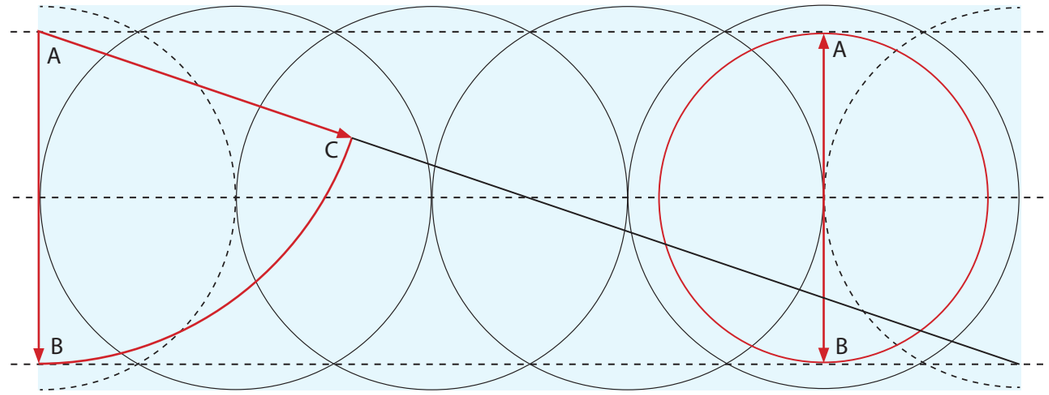
35



Drawing 35 shows a 4 circle chain, in black line, superimposed on the barn's measured footprint. Where the chain circles interlace, at the black arrows, an alignment through the intersections generates the interior face of the long walls. The exterior face is tangential to the circle circumferences.

The dimensions given on the left, 11 feet radius and 22 feet diameter are those of the actual barn and show how a 4 circle chain drawn to 11 feet radius generates the barn's footprint proportions on the ground[7]. The X feet diameter on the right is necessary for setting out the barn at full scale on the ground and, obviously, defines the barn's interior width. It's geometrical length is crucial to the barn's design but it's actual dimension is irrelevant. It is a reality of geometrical design that numbers and dimensions are of little value because they translate the intrinsic propotionality of geometry, as a spatial language, into a numerical language devoid of proportions. So the 11 feet radius that defines the barn's 4 circle chain is its sole dimension.

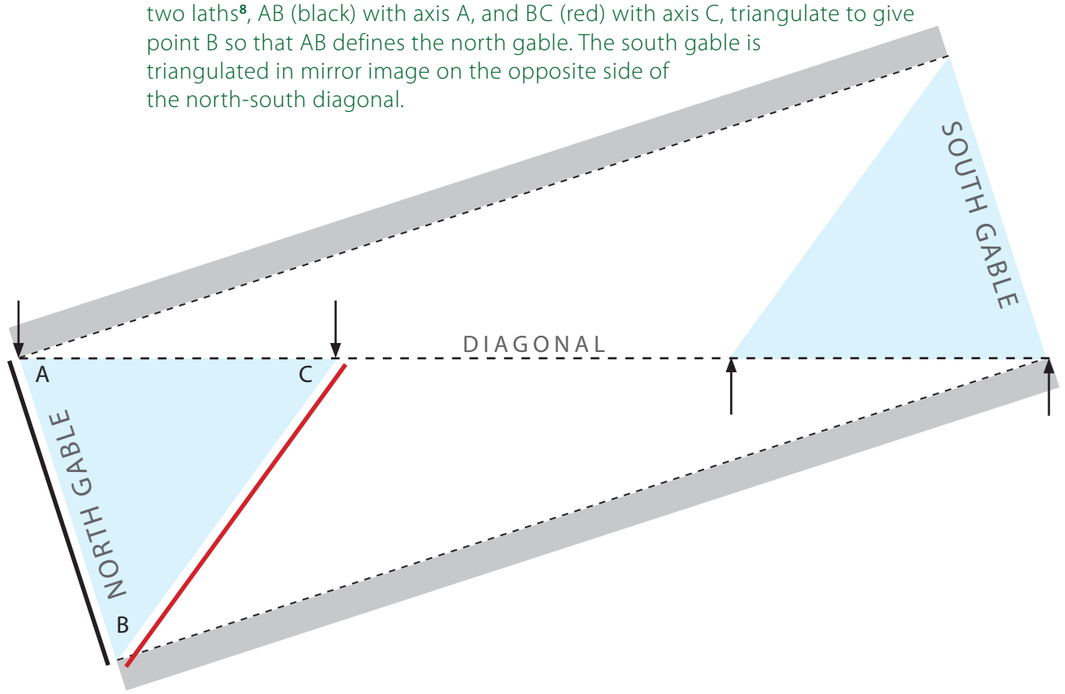
36



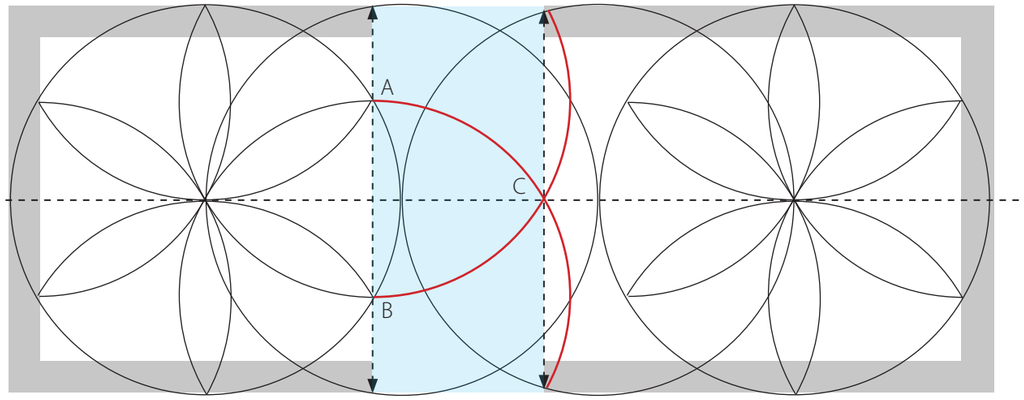
Drawing 36 shows the barn's floor area in blue tone and the 4 circle chain that generates it. The diagonal is shown running between the inner faces of the long walls where they extend to the outer faces of the gables. The drawing shows how the diameter between the long walls across the barn's interior, AB, is found on the right and its equal is found on the left gable. If the diameter AB is used as a radius from axis A, on the left, an arc can be swung from B as far as the diagonal at C. It follows that AB and AC are equal and the distance from B to C can then be found. The triangulation between ABC can be taken from the design and replicated at full scale from the north south diagonal on the ground. If the design, above, is drawn to a 5½ inches radius it would be at 1:24 scale.

Drawing 37 shows the north gable triangulations set out on the ground from the full scale diagonal. Looking at the diagonal sector AC it can be seen that two laths[8], AB (black) with axis A, and BC (red) with axis C, triangulate to give point B so that AB defines the north gable. The south gable is triangulated in mirror image on the opposite side of the north-south diagonal.

37

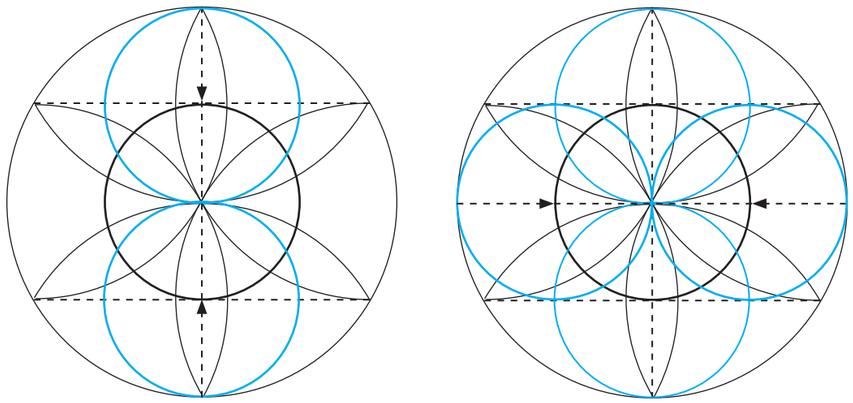


38



In drawing 38, in an additional development of the barn's footprint, a daisy wheel is introduced at opposite ends of the 4 circle chain. In each case the petal tips closest to the gables provide the gable interior face alignments and define the gable wall thicknesses. Further, with the left daisy wheel using the distance between petal tips A and B as a radius, two arcs are drawn, in red line, towards the centre of the barn to intersect at C and continue as far as the long walls. An alignment across the barn through points A and B and a parallel alignment through point C generate the threshing floor, shown in blue tone, and the width of the doors on either side.

39



Designing the Barn Section

Drawing 39 shows how 5 circle geometry can be developed from the daisy wheel. In 39, left, links drawn between the wheel's petal tips intersect, at the black arrows, to give the axes of two blue circles, each of which is exactly half the primary circle in diameter. A third circle, drawn in black line from the primary circle's axis, has the same diameter and the circles combine to form a vertical 3 circle chain. Drawing 39, right, shows an identical 3 circle chain on the wheel's horizontal axis and the two chains together form a 5 circle geometry within the boundary of the primary circle. The 5 circle geometry is the foundation of the barn's cross-section and is shown superimposed on the photograph of the south gable's interior wall in photograph 40.

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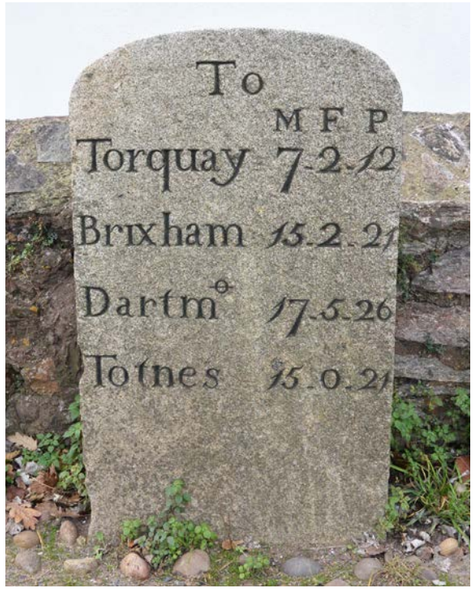
40

41



Rod, pole and perch

The milestone in photograph 41 can be found at Shaldon on the South Devon coast, at the opposite end of the bridge across the Teign estuary from Teignmouth. The distances to Torquay, Brixham, Dartmouth and Totnes on the milestone are given as MFP or miles, furlongs and poles. The word furlong derives from agricultural ploughing terminology *furrow-long* and there were eight furlongs to a mile. Rod, Pole and Perch are three words with the same meaning: a dimension of 16½ feet. A double Rod is 33 feet and it is this dimension that gives rise to the barn's width, 22 feet, and the radius of the circles that form the 4 circle chain footprint, 11 feet. The following chart shows the relationship between these dimensions –

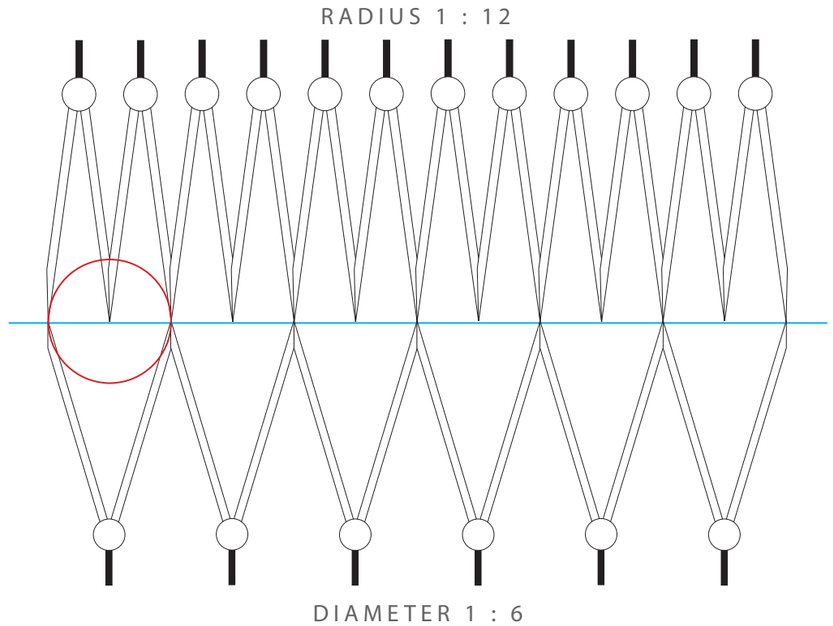
1/3 Rod	2/3 Rod	1 Rod	2 Rods
5½ Feet	11 Feet	16½ Feet	33 Feet

11 feet and 33 feet are steps along a set of mnemonic dimensions that are easy to count and memorise. They derive from counting to 10 on the fingers and can be expressed as either single or double digits. Thinking in Imperial feet and inches, any number in inches, say 33, is in 1:12 ratio to 33 feet.

1	2	3	4	5	6	7	8	9
11	22	33	44	55	66	77	88	99

These Rod based dimensions are found in many medieval buildings. The facade of Salisbury Cathedral is 99 feet wide. The crossing at Ely Cathedral is 88 feet square, the nave is 88 feet wide externally and 77 feet internally. The difference is 11 feet which, halved, gives wall thicknesses of 5½ feet, exactly the same as the depth of the foundations. In Ludlow, Shropshire, the town's burgage plots were set out to 33 feet in width. The barn, with a width of 22 feet, was clearly laid out using this numerical system.

42



Stepping out

Stepping out is a frame carpenter's technique for taking a divider dimension from a scale drawing and enlarging it to full scale along a chalk line. The chalk line, a fine builder's line housed in a small container filled with powdered chalk, is stretched taut between two predetermined points, lifted under tension at its centre and then allowed to snap down so that it deposits a precision chalk line on the chosen surface. In timber framing, the chosen surface is usually a corner post, sill, wall plate, principal or common rafter, etc. With a design drawing at 1:12 scale in inches, the dividers would be set to the radius of the primary circle and stepped along the chalk line twelve times to give 12 feet at full scale. This is done meticulously so that the dividers walk the line from point to point with literally pin point accuracy.

Drawing 42 demonstrates how doubling the primary circle's radius to a diameter has the benefit of halving the number of steps. This is an important technique when working with high scales such as 1:24 or 1:48 where counting errors could occur. Halving and doubling dimensions fits well with the geometrical use of compasses and dividers to generate a series of proportionally related fractions based on the 33 feet double rod –

FRACTIONS[9]

1 1/32	2 1/16	4 1/8	8 1/4	16 1/2	33

The smallest fraction is often found in traditional carpentry as the diameter of peg holes for locating timbers and the second smallest as the diameter of circular or half circular carpenters' marks scribed with a raceknife (a small fixed radius divider with a pin on one arm and fine cutting edge on the other for scribing circle circumferences).

43

Stepping out at full scale requires larger dividers than those used for the small drawing board scale design drawings. Drawing 43 is part of a drawing by Matthew Paris who lived circa 1250 and was a monk at Saint Alban's Abbey, just north of London. Matthew kept a diary of events both within and beyond the monastery. In this drawing, King Offa, recognisable by his crown, is discussing a building project with his master mason, identified by the tools of his trade, the waist high dividers and mason's square which enabled the construction of right angles. In the full drawing, which extends to the right, there is a building site with scaffolding, a crane, workers mixing mortar and laying stone blocks for the construction of an arcade.

TURNING BACK THE CLOCK

The invisible years

The threshing barn's build date is unkown but it features on the 1842 Tithe Map. By the time Richard Westcott purchased the site in the Millenium year, 2000, the barn had stood its ground for at least 158 years and was in a poor state of repair. Necessary repairs were made with sections of decomposing cob rebuilt in cob blocks and, where necessary, some corrugated roof sheets were replaced. It was clear, particularly from the demolition of the adjacent farmhouse, that the whole curtilage had suffered from a severe lack of maintenance. In the absence of documentary evidence for either the construction or subsequent use of the barn, the building's life could only be conjectured through imaginative analysis and speculative reconstruction.

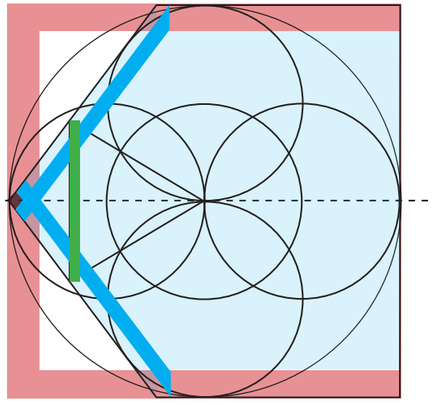
Although the barn's build date was unknown it could be tentatively attributed a build date between the mid 1700s and 1800. Where the date was hazy the design and construction were clear, the design followed the geometrical principles set out on previous pages and the construction followed the logical sequence of stone plinth, cob walls, roof trusses and, finally, thatch. At some time during the construction the cob walls were internally lime plastered. The timing of the plastering was important in a number of ways and this will be returned to below.

The barn's life was marked by decline through lack of maintenance. Almost certainly thatched, like the farmhouse, when newly built, the fact that it was roofed in corrugated iron when Richard bought the site, records the failure of the thatch, the inevitable ingress of rain and the disastrous consequences. There is a memorable phrase in *Conservation Engineering, a Collection of Casework* by Patrick Stow[10] that describes the effects of thatch failure . . . . . *the fine metamorphosis of thatch to waterlogged compost* . . . . . *the slight outward lean of the front walling as the result of roof spreading actions*. The example given is of a masonry rectory but it's roof trusses, like those of the threshing barn, are high collared A frames which, lacking tie beams, have a tendency to spread at the base of the truss. These were clearly the circumstances that led to the threshing barn's re-roofing in corrugated iron and the buttressing of it's leaning cob wall. A further factor that adds credibility to this analysis is that the five roof trusses are not in geometrical locations and, although numbered with assembly marks 1 to 5, are in the order 2 1 3 4 5. This suggests that after the decayed thatch was stripped, the trusses were removed for repair and replaced, probably by inexperienced workers. It was almost certainly during this phase of the barn's life that the top levels of lime plaster on the wall's interior faces was damaged, causing the loss of the upper sectors of some of the geometrical symbols.

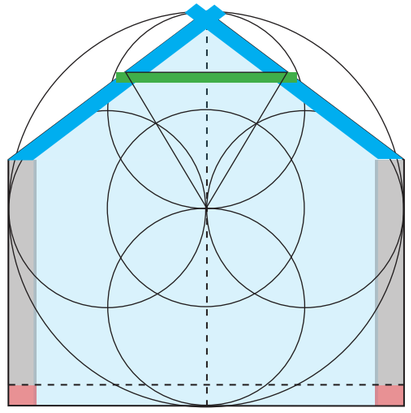
Building the barn

Although the barn's building date remains uncertain the sequence of its construction can be predicted with confidence. It began with a scaled plan scribed with dividers on a board or slate, for without a plan the barn's footprint could not be set out accurately at full scale on the ground. The four circle chain was drawn along a centre line and the wall alignments scribed along a straight edge. Divider readings taken from the plan were stepped out at full scale on the ground along taut peg and cord alignments marking the interior and exterior wall faces and the threshing floor door openings. Once these alignments were in place the foundations could be dug and the barn's stone plinths constructed. Once the masonry had firmed up the addition of cob could begin. A traditional west country building technique, cob combines a mixture of clay based soil, straw, water and sand. Clay would have been dug on site, leaving a duckpond as a byproduct, and wheat or barley straw and water would have been available on the farm. Sand was available from nearby rivers or moors. The percentage of each material was adjusted to provide a workable mixture, wet enough to be pliable, firm enough to hold its shape. Cob construction techniques varied, a sophisticated technique was to ram cob between boarded shutters but the common method was to *lift* the cob mixture by the forkfull to a level height, allow it to firm and then to cut the wall faces flush with a spade. There was a natural building rhythm: while each raised lift became firm, cob was being prepared for the next with each lift adding about two or three feet in height. Scaffolding was erected as the walls grew higher, particularly for the gable walls.

44



PLAN



GABLE ELEVATION

Raising the roof

With the cob walls completed to eaves level on the long walls it was possible to lift the roof trusses into position. The timbers would have been cut and joined in a simple layup on one end of the barn's stone plinth, which served as surrogate carpenters' trestles, so that the trusses were automatically the correct width for the building. This was done before any cob was added.

Drawing 44, left, shows the north end of the barn in plan with the 5 circle geometry that generates the barn's gable section and the corresponding layout of truss rafters across the plinth. The principal rafters are shown in blue and the collar in green (the timbers are not drawn to scale). Drawing 44, right, shows the gable elevation with cob walls in grey above stone plinths and a similar but alternative positioning of the rafters and collar.

While the trusses were cut, laid out and assembled at the northern end of the barn, the longer walls of the southern end were being built up in cob. When all sections of the cob were firm enough to support their weight, the trusses were set in place on horizontal wall plates, to spread the load along the walls, and anchored to each other by purlins running the length of the roof, at either side in the roof plane. At the ridge, a diamond set ridge purlin sat between the V overlap of the principal rafters.

With the barn's wall and roof construction complete two final elements of the barn remained: plastering the interior walls to generate a hygienic surface for the storage of produce and thatching the roof, probably with straw from the farm. Scaffolding, already in place for raising the cob long walls and gables, was also needed internally for plasterers to reach the upper levels of the walls and externally for thatchers accessing the eaves and roof. Theoretically, plasterers inside the barn and thatchers on the roof could work simultaneously but they may have been the same men and, if so, could only carry out one task at a time. Alternatively, if they were different men, plastering had to be carried out before the thatch was complete so that the extensive range of geometrical symbols that cover the walls could be divider-scribed and clearly seen in daylight. The reasons for this become clear when the characteristics of the symbols are carefully examined.

Lime plastering the barn's interior walls

Limestone was imported into Devon for agricultural use and for making lime mortar and lime plaster. Raw limestone and coal from Wales were spread in alternate layers in an open topped conical limekiln and a fire, which was lit at the base, gradually burnt its way upwards through the cone. The burning process, calcining, caused the limestone to fracture. When added to water the porous fractured limestone underwent a violent chemical reaction as it absorbed water, generating heat and causing the water to boil. This further fractured the limestone until, as it cooled, stirring and sieving produced a lime putty or plaster suitable for plastering walls.

Plaster was applied to the interior face of the cob walls to cover their rough texture with a clean, hygienic surface and render them more durable. The timescale for the work depended on a number of interdependent factors: the moisture content of the cob, the plaster's intrinsic set or working time and the weather. Cob walls would dry slowly in wet weather, faster in sunny and windy weather and the wall's water content would sink gravitationally from eaves to sills. The plaster's set was conditional on the moisture content, and therefore the porosity of the cob, the wetter the cob the slower the plaster's set, the drier the cob the faster the plaster's set. But plaster also undergoes a chemical reaction that generates heat as the liquid plaster regains its mineral form and becomes firm enough for it 's surface to be scribed using dividers.

Scribing the geometrical symbols

The geometrical symbols found on the interior walls of the barn are, without exception, circle based and scribed using dividers, which alongside a straight edge and square, are the primary working tool of carpenters and masons. The barn's builders, who would have used dividers to lay out the building's footprint, section and roof trusses, as described above, were present throughout the barn's construction including the interior plastering and were therefore the most likely source of any divider-scribed symbols.

The 169 recorded symbols range from a single open circle to concentric circles, circle chains, 5 circle geometries, daisy wheels and daisy wheels with additional concentric circles. A daisy wheel's primary circle or circumference contains six further internal arcs, making seven arcs in all. So, if every symbol was a daisy wheel the total number of scribed arcs would be 169 x 7 = 1183. Bearing in mind that a daisy wheel has to be scribed carefully, as each successive arc journeys across the primary circle to meet others at precise petal points on the circumference, it would take a considerable time to scribe so many with accuracy. Simplifying the numbers for some maths, if there were 150 daisy wheel symbols and it took two minutes to scribe each wheel it would take 150 x 2 = 300 minutes ÷ 12 = 25 hours = 2 twelve hour working days. This rough estimate is based on my own experience of chalk drawing similar sized demonstration daisy wheels on a blackboard. There are other considerations: no scribing can take place until the plaster has undergone its chemical reaction and begun to set and, conversely, once it has fully set it becomes hard and more difficult to scribe. So there is a window of working time that, as mentioned above, depends on the porosity of the cob, the mix of the plaster, the weather and, additionally, the time it takes to scribe 169

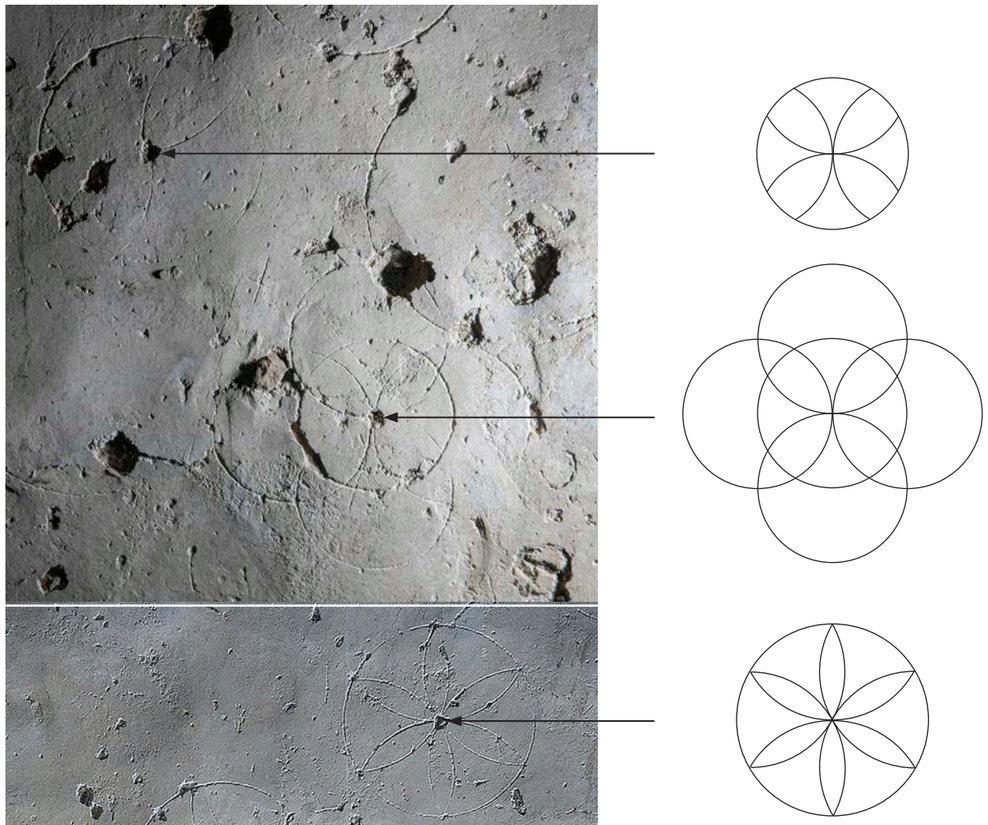
geometrical symbols, the available number of dividers, the number of people carrying out the scribing and their level of skill. And above all it needed adequate light levels so that the act of scribing was clearly visible as it was carried out. When Richard and I assisted Chris in photographing the symbols we needed to use oblique laser lighting to illuminate the symbols for the camera and this suggests that the actual scribing was, before the advent of artificial lighting, carried out in natural daylight either before or during the thatching of the barn's roof. The fact that the majority of symbols were scribed in the southern end of the barn on the east side suggested that the north end of the barn and west side were thatched first, to leave light as long as possible for the majority of the scribing.

Keeping the possible number of people scribing in mind and looking closely at the symbols it is clear that they are by a number of different hands. The simplest distinction is between the symbols that are inscribed with precision and those that are not, the difference suggesting the possibility that the lead builders scribed symbols as examples of technique and that their apprentices or labourers then tried their hands. This theory is reinforced by the fact that the two major geometries, the daisy wheel and 5 circle geometry, were scribed at the top of the wall where they could be clearly seen. The other major geometry, the 4 circle chain, used for floor plan layout, was scribed low on the wall just above the masonry plinth. Much of the wall space in between is covered by an interwoven mesh of fully or part drawn symbols, many of which are far from perfect. The master and novice theory introduces another factor because demonstrating geometrical constructions is usually accompanied by verbal explanations. So demonstrations followed by trial and error attempts at scribing, questions, answers and discussion would all take time. However, the availability of additional pairs of dividers and additional numbers of those scribing symbols would have cut the timescale so that, for example, twice the number of dividers could halve the time and twice the number of scribers halve it again. This would cut scribing time to two days at the most and would fit the plaster's natural setting timescale.

Yet another factor, in terms of scribing, is to consider the farm's family and workforce at the time. There was little mechanisation beyond horse driven mills, such as the simple rotary cider mill, and horse drawn ploughs and carts. Manual labour was intensive and probably included members of the family including children. The construction of the barn would have been an exciting event and the scribing something completely outside the farm's day to day experience. So the total number of those involved in watching or actually scribing could have included builders, builder's labourers, the farm family including children and farm labourers. Remembering that historically, barn building was often assisted by neighbouring families, the total number present during the scribing could expand to a small crowd, walking through the lanes to the site, many of whom might want to try their hand at scribing.

Photograph 45 shows a shorthand 5 circle geometry, to left, and full 5 circle geometry, lower right, with the geometries shown in the margin. Photograph 46 shows two daisy wheels, the top right wheel accurately scribed and the lower left with two upper petals that are well scribed but the remaining four far from accurate and probably someone's first attempt at scribing, Photograph 47 shows imperfect concentric circles, top right, and imperfect daisy wheels, centre and left, incomplete, inaccurate and overdrawn.

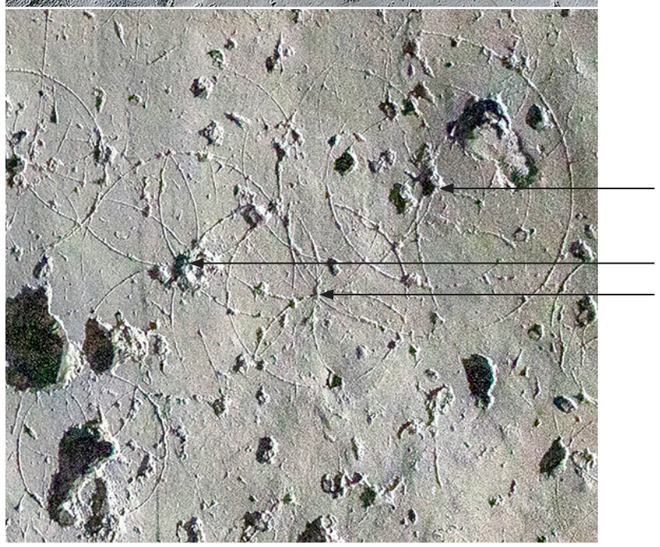
45



46

IMPERFECT DAISY WHEEL

47



IMPERFECT CONCENTRIC

IMPERFECT DAISY WHEELS

ARCHITECTURAL GEOMETRY • A RARE GEOMETRICAL RECORD FROM RURAL DEVON

Why?

The question remains. Why were the walls scribed with geometrical symbols? The answer must be in two stages, first regarding the walls and second, the symbols. The walls were in effect giant drawing boards, not unlike but significantly bigger than a modern white board, and were a substitute for parchment or paper surfaces but more suitable than either for large drawings. Parchment was expensive and limited in size to the skin of the sheep or goat from which it came and, once a drawing had served its purpose was scraped clean with a knife so that it could be used again, and again, and again. It was extremely durable and tended to be used for high quality illuminated ecclesiastical book productions such as the Book of Kells and the Lindisfarne Gospels. Paper was even more limited in size and had the disadvantage that, if used for a building plan on site, could easily become damaged through use or dimensionally distorted if it became wet from rain.

Scribing on plaster originated in the historic horizontal tracing floors like those that survive to this day at York Minster and Wells Cathedral. The floors were used by masons for laying out the geometry of vaults and arches at full scale so that templates could be made for cutting voussoirs and other architectural details. In the Galilee porch at Ely Cathedral similar geometries are scribed into a vertical wall surface. Though the tracing floors predate the threshing barn by many centuries they can be seen as the seed from which the idea grew so that when the barn was built geometrical scribing was part of the construction process. We can look at the purpose below but it is easy to see why barns in particular became chosen sites for scribing. First and foremost they were not domestic accomodation, where scribed walls might not be particularly popular and, unlike farmhouse kitchens or parlours, had significantly larger wall surfaces available for scribing. Arnold Pacey, in his book *Medieval Architectural Drawing* notes that the predominant feature of the tracing floors is the presence of scribed circles and arcs of circle. So, from the earliest days, scribing on plaster was of compass or divider based geometries and this holds true for the threshing barn.

Looking back at photographs and drawings 23 - 25 for Saint Andrews Church, Sutcombe, Devon, 26 -29 for the Barley Barn at Cressing Temple in Essex and 30 - 32 for Tŷ Mawr, Castle Caereinion, Montgomeryshire in Wales, it can be seen that in each case a geometrical symbol or a circle based geometry facilitates the design of the building's floor plan, cross section or long section. The geometrical symbols used in the design of the above examples are also those found divider-scribed into the threshing barn's walls so there is a direct evidential link between the design of actual buildings, as demonstrated above, and symbol driven architectural design in general. The primary geometries are the daisy wheel, five circle geometry and circle chains, all of which appear on the barn's walls.

Photograph 48 shows an example of five circle geometry with its axis at A and a daisy wheel with its axis at B with both additionally scribed with concentric circles (to be considered further on). Photograph 49 is of Laurie Smith, left and Richard Westcott, the barn's owner, taken by photographer Chris Chapman when the three of us were recording the symbols. The top photograph gives a clear idea of the actual scale of the symbols and the lower photograph shows how visually elusive they are, even under artificial light.

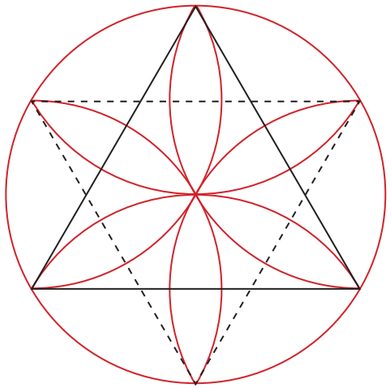
48

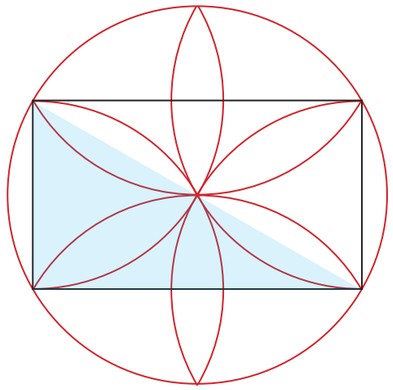
49

The 5 circle geometry and the daisy wheel are geometrical archetypes, the fundamental prototype geometries that lead to the two classic historic design methodologies: ad Quadratum and ad Triangulum. The terms are often translated as designing from a square and designing from a triangle but this is a widely held and erroneous comprehension of the Latin. The crucial element of the terms rests in the prefix *ad* which translates as *towards*. So ad Quadratum means *towards* quadration and ad Triangulum means *towards* triangulation, both terms providing stepping stones from the archetype towards actual building design.

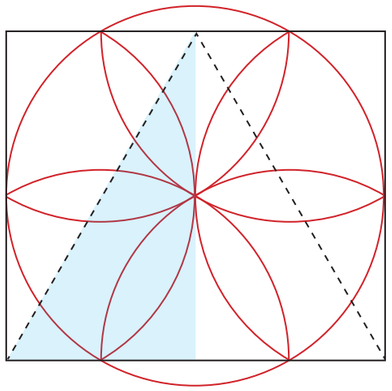
Drawing 50 shows how the daisy wheel's alternate petal tips are linked, upper left, to give equilateral triangulation, the two mirror image equilaterals combining to form the star of David. The configuration of the star generates a ring of six smaller equilaterals with a hexagon at their centre. The 4 point rectangle that links four of the daisy wheel's petal tips, upper right, can be divided along its diagonal to form a right angled triangle with 30° 60° and 90° angles, a perfect carpenter's or mason's set square, lower right. The 6 point rectangle, lower left, which passes through all six of the daisy wheel's petal tips, also embodies two 30° 60° 90° right angled triangles which, back to back on the rectangle's base line, form a large equilateral triangle that rises to the centre of the rectangle's top line. These geometries lead on towards floor plan and sectional construction.

50

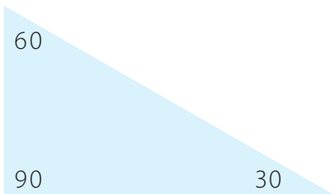




4 POINT RECTANGLE



6 POINT RECTANGLE



SET SQUARE

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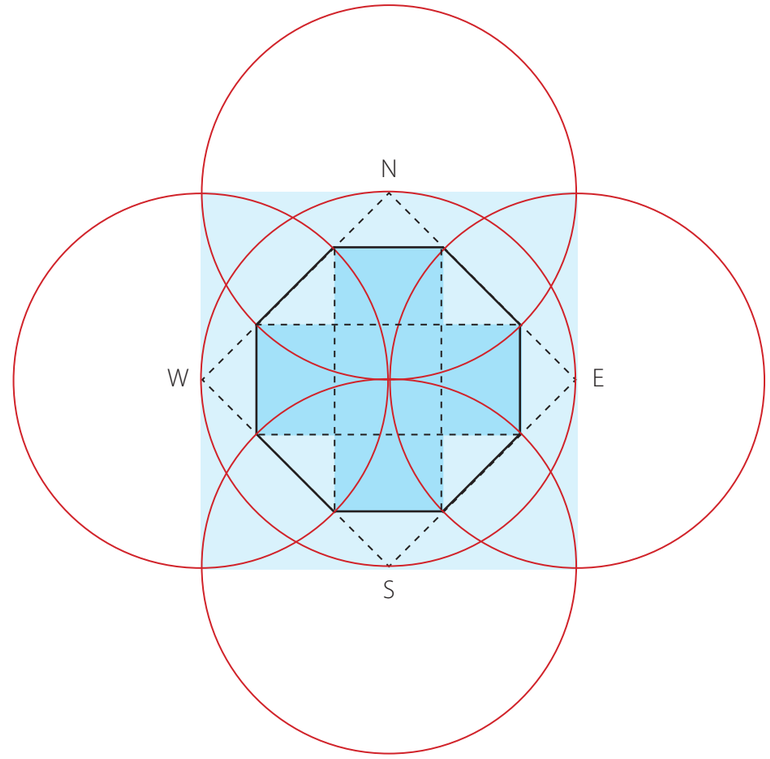
51



Drawing 51, which shows 5 circle geometry, also shows how the four outer circles intersect each other at four points that define the corners of the perfect square, shown in pale blue tone. Drawing a square using 5 circle geometry is the fastest manual way of doing so, far quicker than the more orthodox method of drawing a base line, constructing two verticals at right angles to it and then a top line at the correct height parallel to the base. 5 circle geometry does all this from a single dimension: the radius of the primary circle. As the primary circle is drawn it generates a diameter (= radius x 2) that is equal to the sides of the square formed where the outer circles intersect. The outer circles are drawn from the primary circle's north, east, south and west poles to the same radius. The crossing at Ely Cathedral, which is laid out to 5 circle geometry, has a primary circle radius of 44 feet to give a diameter of 88 feet, the distance between the outer faces of the nave, transepts and choir.

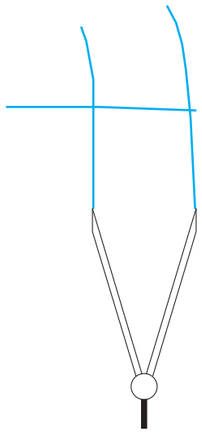
5 circle geometry is the source of further multi-faceted forms derived from the square. The drawing shows the construction of an octagon, the section of the lower half of the spere posts, and cruciform upper half, in dark blue tone, in the hall nave cross passage at Tŷ Mawr, Castle Caereinion, Montgomeryshire. The nave primary circle diameter at Tŷ Mawr is 16½ feet (= 1 Rod) between the outer faces of the aisle posts so the initiating radius was 8¼ feet.

It is noticeable that these two archetypal geometrical constructions, shown in photograph 48 at A and B, are emphasised by concentric circles, like underlining or highlighting an important word or phrase in a text.

The writing on the wall

As well as the 169 divider-scribed geometrical symbols on the barn's walls there are the name and initials of two people, presumably men and possibly those of the lead builders. Photographs 52 and 53 show the initials TH and the name WILL respectively, with the lettering overdrawn and reproduced in white below the actual lettering. The initials TH are scribed at a large scale to the right hand side of the south gable's pitching window, just above its sill level. The name WILL is scribed in smaller lettering in the top left quadrant of a large circle on the barn's east wall. Both inscriptions have the same character as the scribed symbols and it seems reasonable to think that they were scribed as signatures at the same time. A confirmatory aspect of this theory can be found in the H in TH which has parallel verticals that are curved above the central horizontal and straight below it, two lines that could have been scribed downwards using a dividers' two pins, as shown in the adjacent drawing, and thus linking the lettering with the symbols. Further, the T in TH and the LL in WILL all have the same simple form of serif. Stylistically, this links the two inscriptions and also tells us that the builders were literate men.

52



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Diagonals

The fact that the barn was set out from a north-south diagonal alignment might raise some modern eyebrows when, today, we commonly consider buildings in the three dimensional terms of length, width and height and set them out on centre lines. The reason for the difference can be found in the transition over time from geometry as a state of the art design system to measurements and dimensions as a numerically focussed design methodology. The threshing barn was built when geometry was still the design process of choice whereas today it is rarely used and numbers, aided and abetted by calculators and Autocad, reign supreme. But the threshing barn's diagonal had an absolute logic about it as the footprint's largest dimension and this was laid down as the first step in setting out. Co-incidentally, there is an up to the minute parallel in the 21st century world of computing where the size of a computer monitor is also expressed as it's diagonal. In both cases the diagonal embodies the relationship between length and width but is expressed as a single number rather than two. Other diagonals can be found in timber framed buildings, the most noticeable being the diagonal dragon beam support at the corner of jettied buildings. It is highly likely that dragon beam is a corruption of, or a humorous take, on diagonal beam.

Of course, comparing the diagonals of a square (which should be identical) is the standard test for a square's accuracy and the point where the diagonals intersect is the axis for a circle drawn through the square's four corners. It follows that the diagonal of the square is simultaneously the diameter of a circle passing through its corners.

Reading the walls

The process of recording the geometrical symbols inside Hayne threshing barn was a site specific study. With the symbols photographed, gridded and counted, their different geometries recognised and their characteristics found in examples of historic building design, it might seem as if the task has been completed but, beyond Hayne's walls, there are other points of view.

A prevailing view categorises almost any type of mark on a building's walls as an apotropaic sign, a sign that wards off malignant spirits. I have seen this attribution given to carpenters' assembly marks, marks that have the following functions: first to apply a visually recogniseable code sign to each cross wall truss in a building's frame including the gable frames and roof planes and, second, to indicate every joint in each truss. These codes are applied as each truss or roof plane is test assembled on trestles and are necessary to enable the wall's reassembly on site when the building is erected. There are strict rules governing the placing of carpenter's marks. First on the external faces of a frame's four external walls, where all timbers are framed absolutely flush, a necessity for perfect weather protection and, second, on interior walls the carpenter's marks face into the superior room. So the marks arise from the practical considerations of carpentry and the language is marked using the carpenter's tools, dividers and the race-knife (a fixed radius gouge like a small compass for scribing circles or half circles). In the case of all these marks, which are instantly legible in carpentry terms, the term apotropaic has no relevance and tells us nothing about the frame. The following pages look at a range of interpretations relating to the marks found on buildings.

POINTS OF VIEW

Each time Richard Westcott, the barn's owner, photographer Chris Chapman and I spent time at the barn to record the geometrical symbols scribed into the lime plastered interior walls we debated their meaning. On one such occasion Richard told us the following story[11] –

A countryman's point of view

In the early 2000's I worked with an intriguing old countryman, Ian Mock, who was very skilled with his JCB (actually a Ford) which he called his mate and best friend. He used it to reach high places, could do very fine work with it - almost strike a match, as the saying goes! - and earned his living as a contractor, digging trenches, ponds etc. He originally worked with Bill, the old farmer from whom we bought Hayne, which was how I met him. He was at times extremely reticent - I think there were days when he might not have said anything to me - but I got used to this, and enjoyed his (often grumpy!) company, not least because I admired the many skills he could deploy and learnt much from him, when he did speak. Well, he knew about daisy wheels - had seen them before, and pointed them out to me as harvest symbols. I think it was more as fertility symbols and aspiration for fruitfulness rather than protection. I wish now I'd asked him more, and taken better note but the main thing though is that he knew about them and wasn't surprised to see them - which perhaps suggests that there may be many more in barns locally?

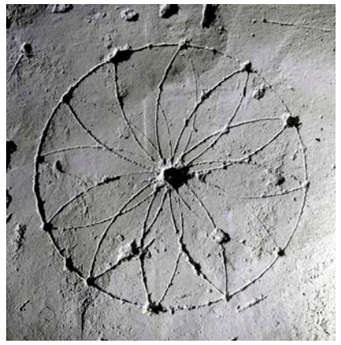
Ian Mock's opinion is interesting because it records a first hand view of the geometrical symbols that were used in farm buildings within his local agricultural landscape and it is significant that his focus was positive rather than negative. So *not* a symbol to ward of malevolent spirits, the evil eye or witchcraft but a sown seed, encouraging germination and nurturing growth towards fruition. This is a view that fits the daisy wheel well because it's six geometrically radial petals mimic those found in Devon's springtime daffodil, the flower of which acts as a golden, high visibility helipad beacon to attract nectar seeking bees. The bees, in turn, construct their hexagonal cells to the same daisy wheel geometry because they form a perfect continuum free from intervening space and thus optimise the use of space within their hive. The daisy wheel is preordained in nature whether we scribe it or not and, in this context, can be seen as a symbol of life. There are, however, other views.

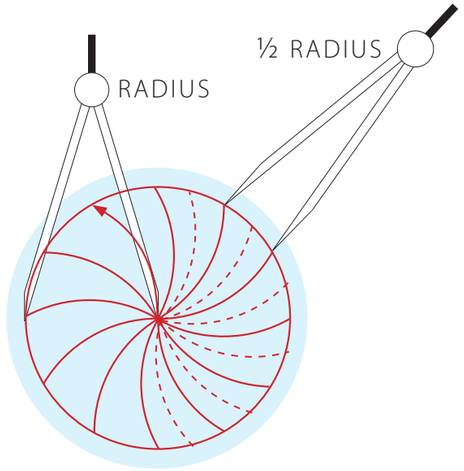
A carpenter's point of view

A different view of the daisy wheel can be found in an article by the carpenter Peter Massey of Dolmen Conservation in the Mortice and Tenon (the Carpenters' Fellowship Journal of Timber Frame Carpentry). In M&T 23, Spring 2006, his article *From Leaf to Lych Gate*, described the process of selecting, felling and converting timber for the frame including durns cut from the buttresses of trees which were inverted in pairs to form gothic window arches. Every element of the frame, including a shingled roof and the pegs that held the frame together, was cut from oak. Explaining his peg making method and linking the daisy wheel's six petal tips to form a hexagon, Peter wrote *Our pegs are six sided which, in my experience, works better than eight sided or round pegs because hexagonal pegs are less likely to jam whilst being driven home as they ride on the ridges of the six points, which also fits the daisy wheel magic*. Finally, Peter concluded, *The last thing to do was to carve my mark on the frame which I do in situ to record the end of work. I have put this on my repairs and new work for the past 30 years. So* Peter's mark was a personal signature in a widespread tradition that many carpenters follow. The lychgate is at Petham Parish Church, about seven miles from Canterbury.

Another carpenter's signature mark was featured in M&T 30, Winter 2007 in an article that, sadly, recorded the untimely death of carpenter Jake Jackson. His mark was based on the twelve points of a double daisy wheel, like that found on the threshing barn wall at Hayne, photograph and drawing 54, left, but depicting a single side of each petal, right, a symbol that is easily scribed with dividers. The arcs are drawn using the wheel's radius from twelve consecutive points that are half a radius apart around the circle's circumference. Jake's symbol was first scribed as shown below and then each sector was marked with a centre lined arc, some of which are shown in dashed line. Jake then cut between the lines with a chisel so that the solid lines remained level with the surface of the timber but the space between them was a V-shaped channel. The rise and fall of the symbol's surface, which held light and shade, made it clearly visible.

54





A historic house owners point of view

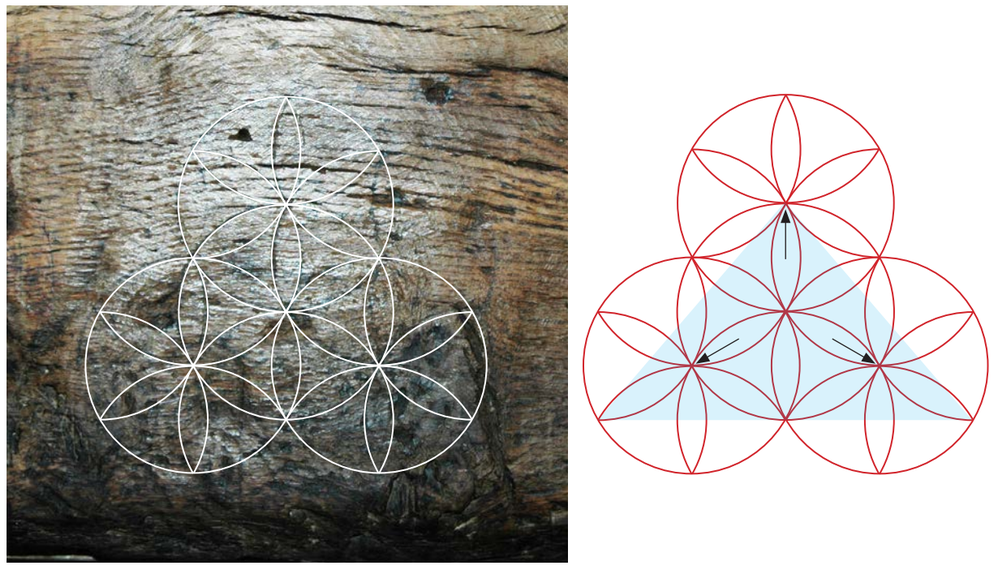
I lived in Wales for over twenty five years and was familiar with the Anglo-Welsh border towns. My favourite was Ludlow and, following the narrow backwater pathway around the graveyard of Saint Laurence's Church in Ludlow, you come upon an extraordinary three storey jettied timber frame porch projecting from a high masonry wall. This, at ground level, is the entrance to The Reader's House, my favourite house, named after its function as the residence of the person delegated to read the rector's sermons in the church, a reflection of the affluence and influence of both Ludlow as a town and the rector as an individual. On one occasion, as I walked towards the house, I stopped to chat with two gardeners who were laying out a small public garden beside the Reader's House and they told me the new owners were happy to meet anyone who was interested in the house. *Just knock on the door* they said and my knock was answered by Alan Laing[12]. Alan welcomed me in and began his tour, *Let's start in the kitchen. I'll show you the witch mark.*

A geometer's point of view

Unknown to Alan I had visited the house before when Simon Buteux, the previous owner, had carried out a major repair programme. I had already seen the mark[13]. It was a geometrical archetype in the form of a trefoil daisy wheel and was scribed with absolute precision into the kitchen chimney lintel. Alan continued his explanation, that *the witch mark kept malevolent spirits from entering the house by way of the chimney*. I had heard this many times before and had always been troubled by the irrationality of it. If a malevolent spirit could see the symbol it had to be standing where Alan and I were, in front of the fireplace inside the room and, clearly, this was a policing failure in terms of protecting the house. So, surely, to attain it's enforcement objective, the symbol would be better placed on the chimney stack or chimney pots at the point of entry. It seemed to me that there were better reasons for the placing of the symbol where it was, close to head height in clear view of the human eye where it was more a watch mark than a witch mark. Or was it a design icon, a geometrical design signature, divider scribed where it could be clearly seen as reference and where better than on the chimney lintel at the heart of an individual room where people gathered.

Between the two ownerships I had researched the symbol's potential as a design icon and had found that it governed the proportions of the great dormer on the rear elevation of the house. Photograph and drawing 55 shows the trefoil daisy wheel on the chimney lintel, overdrawn in white line, left, and the dormer triangulation derived from the geometry, right. Drawing 56 shows the geometrical dormer suprimposed over a measured drawing of the full rear elevation of the house[14]. The zigzag diagonal braces immediately below the dormer are part of the new build on a deeper wall plate riding on the original shallower wall plate emphasised in green tone. The drawing shows part of the rear elevation of the house and the ground floor window shown in blue tone is the kitchen window. The fireplace and symbol are on the front wall at the far end of this room.

55



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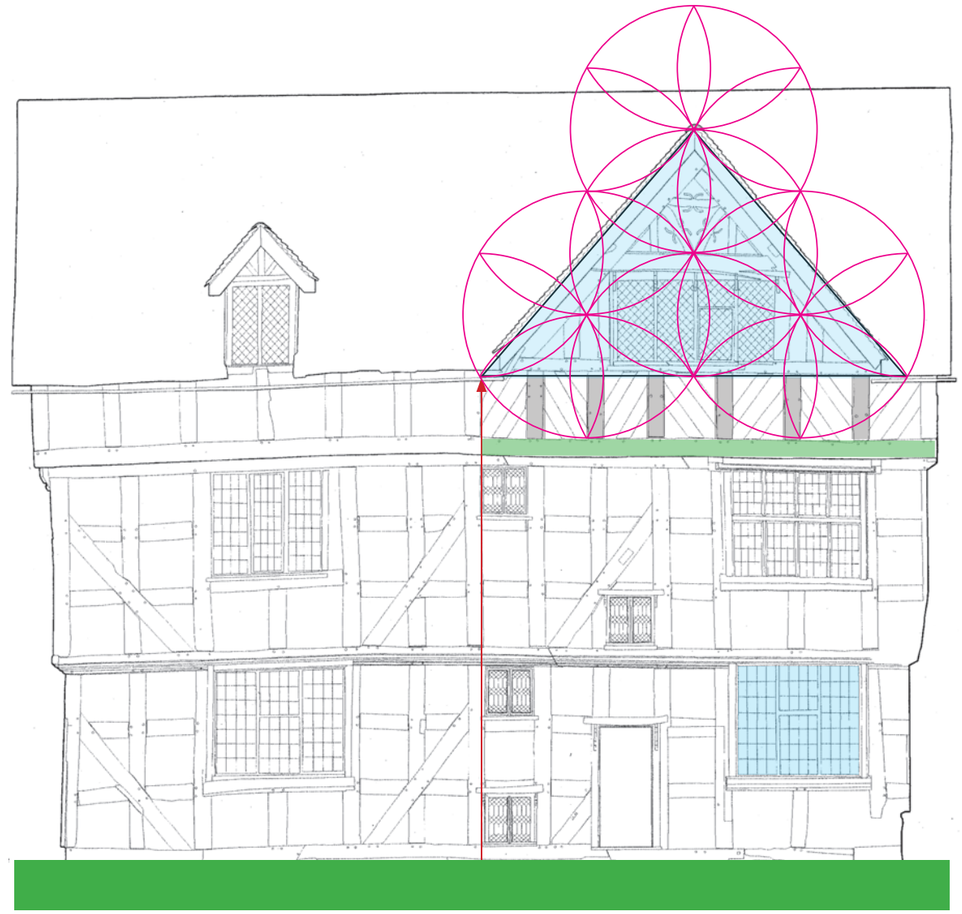

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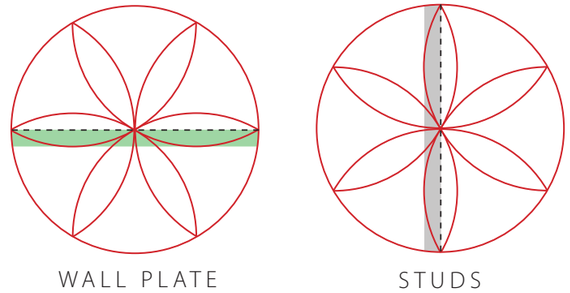
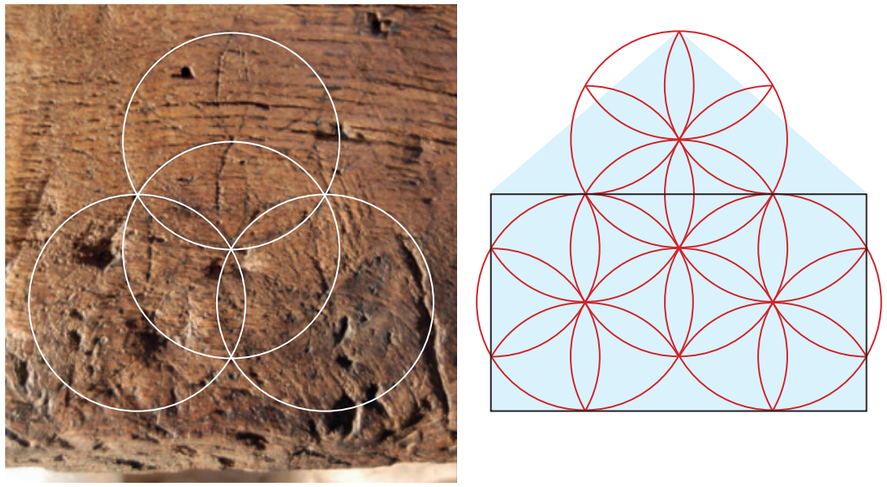


Drawing 57 shows how the dormer's trefoil daisy wheel geometry also generates the horizontal wall plate and vertical stud's timber dimensions by halving the maximum width of the daisy wheel's petals. The timbers are therefore in a specific proportional relationship to the full dormer. The whole Reader's House frame follows geometrical design principles but the focus here is on the specific role of the trefoil daisy wheel archetype, why it was divider scribed into the fireplace lintel and whether the term witch mark, which tells us nothing, has any credence at all when the geometry reveals it's own eloquent story if we bother to read it.

At the Reader's House the trefoil daisy wheel archtype was used solely to determine the proportions of the great dormer, a structure exactly half the length of the building's footprint, built during a raising and reconstruction of the whole roof. A second, alternative and more comprehensive use of the archetype can be found just 40 miles away at Titley in Herefordshire and is recorded in Vernacular Architecture, Volume 49 2018 by the architectural historian Duncan James. In his article, *Carpenters' Assembly Marks in Timber Framed Buildings*, Duncan records an identical trefoil daisy wheel, to that on the Reader's House kitchen chimney lintel, similarly divider scribed into a chimney lintel at The Old Priory. Photograph and drawing 58 shows the trefoil overdrawn in white line, left, and how it generates the building's section, right. Describing truss 2, Duncan refers to the daisy wheel and circles on the frame timbers as apotropaic marks but, as with the Reader's House, drawing 59 demonstrates that the symbols are the key to the building's design, including the scaling of timber dimensions, in the lower right daisy wheel[15].

58



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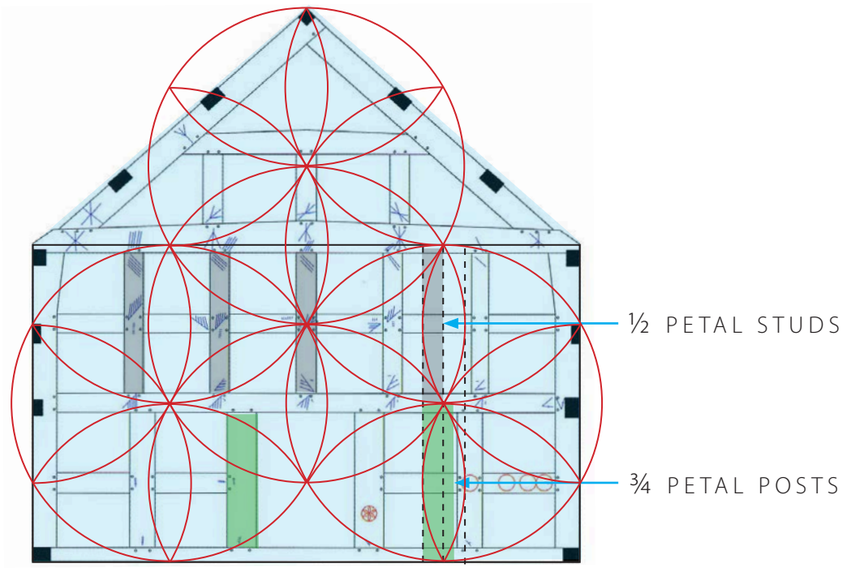

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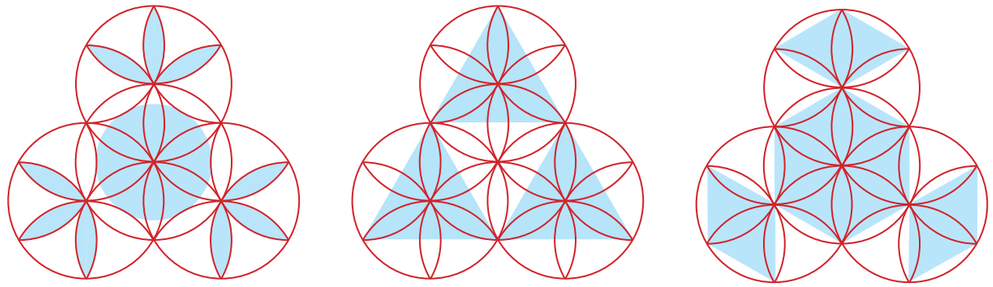
A third example of the trefoil daisy wheel in building design can be found at Triangular Lodge, Sir Thomas Tresham's warrener's lodge, built in Northamptonshire between 1593 and 1597. Tresham's innovative conceit was to link his own name with the Trinity in a building that was an equilateral triangle on plan, a concept that almost certainly arose from the compass construction of his personal trefoil logo, an idea that sprang from Tres (the French for 3 found in his own name). Refusing to renounce his Catholicism, he suffered the inevitable fines and imprisonment but expressed his religious convictions secretly in two remote buildings, Lyveden New Bield, on a cruciform plan symbolic of Christ's cross and Triangular Lodge, symbolic of the Trinity. The symbolism is unremitting with three exterior walls forming the equilateral plan, three floors, three windows on each floor and three gables crowning each face of the building. Each wall is 33 feet, a double Rod, in length.

The small basement floor windows are simple identical trefoils. The centre floor windows are a combination of squares and diamonds with trefoils at the diamond's corners. The nine upper floor windows are all based on trefoil daisy wheel geometry with a different geometrical interpretation in each. On the south-west facade the left window emphasises the daisy wheel's vesica petals, the central window has equilateral triangle glazing and the third, on the right, hexagon and diamond glazing. Drawing 60 shows the three variations and photograph and drawing 61 shows the trefoil window with a blind masonry primary circle, blacked in to appear as glass from ground level, and with the triple Trinity petals of each radial foil as glass.

60



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ROUNDING THINGS OFF

Scribing a circle with dividers, the static pin at the axis pirouettes as the moving pin at the circumference turns full circle to end it's journey exactly where it began. This is true of all circles, that they depart from their origin but return to it, whatever their scale, and their track has an eternal and perfect symmetry. We can observe circular symmetry when we watch the sun or full moon or when we look in a mirror at the circular irises of our own eyes. But the sun, moon and our eyes also have three dimensional symmetry and exist as spheres, the most perfect universal form in which the maximum volume is held within the minimum skin. In scribing a circle we are tapping into a universal, spatial language that gives us control of symmetry and proportions.

Circularity and angularity

Circularity and angularity are two fundamental, opposing but simultaneously harmonic, aspects of geometrical thought. Circularity can be seen in living things, in the section of a tree trunk or flower stem, the free blowing flower head of the dandelion or the defensive sphere of a hedgehog. Angularity can be found in the forms of minerals that crystalize into triangular, square and hexagonal sections such as the cliff height basalt columns of the Giant's Causeway in County Antrim, Northern Ireland. All crystal formations pack densely together without intervening space to form a solid, continuous mass. Circularity, which exists in life forms that are mobile, and angularity, found in forms that are static, can be seen as dynamic opposites like night and day, black and white, right and wrong, male and female, yin and yang.

In cathedral architecture the relationship between circularity and angularity is most clearly expressed in the alternation of cylindrical and angular piers in the arcades that line the building's nave. The supreme example is in the cylindrical piers of Durham Cathedral which are cut with angular patterns of zigzags, chevrons and spirals (when the zigs are omitted and the zags extended). Further, and this is where the geometry is invisible to the naked eye, the height of the Durham cylindrical columns is equal to their circumference so that, if their surfaces were wallpapered and the paper was peeled off, it would be exactly square[16].

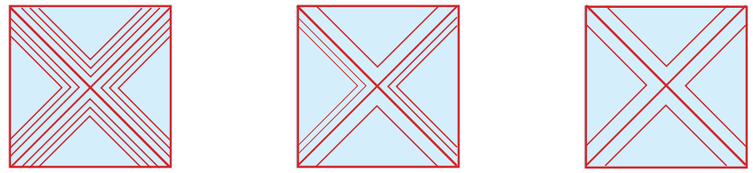
It is important, as we follow the circle's circumference back towards Hayne, to recognise that the relationship between circularity and angularity pervades historic geometrical design, and that the geometrical archetypes that express it are present in the divider-scribed symbols on the barn's walls. The daisy wheel, five circle geometry, concentrics and a circle chain are all there.

My Vernacular Architecture Group newsletter arrives

My VAG Newsletter contained brief reports from the Winter Conference, 2020 on the theme *Marks on Buildings*, the current fashion and focus in all types of marks discovered on all types of building. The reports, by VAG bursary recipients Emma Healey, Ruth Mullet and Coco Whittaker covered: Graffiti, ritual marks and witch marks by Owen Davies; Witches, buildings, charms and curses in Wales by Richard Suggett; The six petal rosette: an evolution of belief by Matthew Champion; Apotropaic marks and symbols by Timothy Easton and Burn marks in buildings by John Dean and Nick Hill.

Owen Davies challenged the term *witch mark* which he said had been widely used in sensationalist articles in the media and often detracts and distorts the popular understanding of marks on buildings, concluding that it is problematic to jump to the conclusion of assuming marks on buildings are directly related to some form of ritualistic practice. He referenced the so-called *witch posts* beside fireplaces in some Yorkshire houses and pointed out that the term wasn't coined until the 1920's and that there was no documentary evidence that the posts were to ward off witches. My take on these posts, which have a square incised with diagonals at the top, is that they are simply capitals, cut by an enterprising carpenter with some distant knowledge of the classical orders, to dignify the vertical post supporting the chimney lintel. Drawing 62 shows three posthead patterns based on diagonals.

62



Matthew Champion is the author of *Medieval Graffiti, The Lost Voices of England's Churches*, a book comprehensively listing every possible type of mark including the six petal rosette, better known to carpenters as a daisy wheel. The text categorizes mason's marks, compass drawn designs, pentangles, ship graffiti, heraldic graffiti, crosses and so on. It suggests that because daisy wheels can be used to construct triangles, rectangles or the complete form of a building they may have been scribed by masons but then reports that because archaeologists have found few examples of dividers and many examples of sheep shears, that shears, owned by most women, were used to scribe daisy wheels. My take on this suggestion is that it crosses the border into fantasy and is a classic example of an untested, unproven and unsustainable view that acquires a viral life of its own and spreads exponentially until there is no stopping it. I decided to put the concept through a practical test and, owning some manual sheep shears, attempted to scribe daisy wheels. The two arms of the shears are designed to cut across each other, through wool, and have a sprung return to facilitate consecutive cuts. Scribing even a single basic circle proved difficult because of the sprung handle's tension. There is no way of changing the radius and locking it and the blade ends are blunt to avoid stabbing the sheep. Conversely, dividers have rigid arms, sharp pins, a means of adjusting and locking the radius, were designed for the job of scribing into masonry or timber and are perfect for the task.

Timothy Easton is the wizard of apotropaic marks and, like Mathew Champion, has made significant and interesting collections of examples. He argues that most marks found on buildings, including burn marks and hexafoils (another term for daisy wheels from their six petals), were made deliberately and were embedded in a culture that sought protection from a range of perceived physical and spiritual threats. While much of his argument is persuasive these attributions also fail to analyse geometrical symbols from a geometrical point of view. I am in tune with the recognition of a spiritual element in the use of symbols but still need an answer to the persistent question of why geometrical symbols could or should embody spiritual meaning.

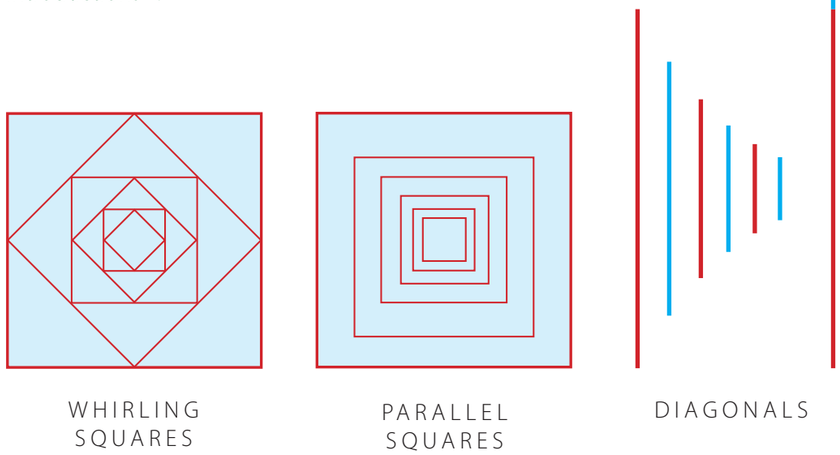
The Trivium, rhe Quadrivium and whirling squares

After reading my newsletter I decided to go back to square one or somewhere near it in search of evidence of any relationship between spirituality and geometry, a journey that lead me to the Trivium and Quadrivium. In medieval education, the Trivium (the three roads, tri = 3, Latin via = road) was an initial period of study that covered grammar, rhetoric and logic. Grammar taught the structure of language, rhetoric taught how to express language persuasively in debate and logic taught how to attain intellectual clarity. The Quadrivium (the four roads: quad = 4, Latin via = road) covered the advanced subjects of arithmetic, geometry, astronomy and music with music as the highest level of attainment. This mode of study had been around since before Christ. The Roman architect Vitruvius (Marcus Vitruvius Polio,100 BC) made specific reference in his *Ten Books on Architecture* to arithmetic and geometry –

> *It is by arithmetic that the total cost of buildings is calculated and measurements are computed, but* ***difficult questions involving symmetry are solved by means of geometrical theories and methods****.*
>
> *Geometry is of much assistance in architecture and* ***teaches us the use of the rule and compasses, by which means we make plans for buildings in their grounds****.*
>
> ***A ground plan is made by the proper successive use of compasses and rule****, which give us outlines for the plane surfaces of buildings.*

The successive use of compasses and rule was the state of play through the great eras of Romanesque and Gothic architecture but in 1460 there was a game changing expansion into square geometry. Two German master masons from Regensburg wrote booklets on whirling square geometry used to proportion cathedral pinnacles. Drawing 63 shows the archetypal whirling square construction, left, and rotation into parallel alignment, centre, where each square represents a rising stage in the pinnacle and where the diagonals of the squares, shown separately and stacked, right, determine the pinnacle's gradually diminishing height from largest element at the base to smallest at the peak. Mathes Roriczer wrote *Büchlein vonder Fialen Gerechtigkeit* (Booklet Concerning Pinnacle Correctitude) and Hanns Schmuttermayer wrote *Fialenbüchlein* (Booklet on Pinnacles), both with elaborately worded introductions[17].

63



For some reason, architectural historians have focussed mainly on Roriczer's booklet but it is Schmuttermayer's introduction that spells out most clearly where the seed of geometry germinates –

> *BY THE GRACE OF ALMIGHTY GOD I have written this little book in order to petition many honorable persons for improvements and refinements in the building of holy Christian churches, and for the edification and instruction of our fellowmen and all masters and journeymen who use this high and liberal art of geometry . . . . . .* ***Fundamentally, this art is more freely and truly planted and developed out of the centre of the circle****, together with its circumference, correct rules, points and settings out . . . . . .*

On Earth as it is in heaven

Fast forwarding through time, we arrive at the Italian architect Sebastiano Serlio, 1475-1554, who wrote *The Five Books on Architecture,* published in Italy during his lifetime but not translated into English until over half a century later. In London in 1611 the books were bound as a single volume, *Printed for Robert Peake and sold at his shop neere Holbourne conduit, next to the Sunne Taverne*. The introduction to the first book opens with –

> *How needful and necessary the most secret Art of Geometrie is for every Artificer and Workeman, as those that for a long time have studied and wrought* **without the same** *can sufficiently witness, who since that time have attained unto any knowledge of the said Arte, doe not onely laugh and smile at their owne former simplicities, but in trueth may very well acknowledge that whatsoever had been formerly done by them,* **was not worth the looking on**.

Serlio's instructions commence from ***A poynt*** which he described as follows –

> *First, you must understand that a poynt is a pricke made with a Pin or Compass, which cannot bee divided into any parts, because it containeth neither length nor bredth in it.*

So geometry begins from a single, almost invisible, point in space and geometrical constructions radiate from it like ripples moving out from a stone thrown into still water, a pattern paralleled in the solar system. The Italian astronomer Galileo di Vincenzo Bonaulti Galilei, 1564-1642, in his scientific search for meaning in the universe, fell foul of the rigid theology of the Catholic church. The church believed the Earth was the pivotal centre of creation and Galileo's geometrical proof demonstrated that the Earth revolved around the Sun. He wrote a dialogue presenting the two opposing views but was imprisoned and forbidden to publish his theories. But his words have come down to us and give a penetrating insight into the presence and meaning of geometry –

> *Philosophy is written in this grand book of the universe, which stands continually open to our gaze, but* ***the book cannot be understood unless one first learns to comprehend the language*** *and to read the alphabet in which it is composed. It is written in the language of mathematics, and its characters are triangles, circles, and other geometric figures, without which it is humanly impossible to understand a single word of it; without these, one wanders about in a dark labyrinth.*

Geometry as a spatial language

Bringing the practical architectural design systems of Vitruvius, Roriczer, Schmuttermayer and Serlio and the heavenly observations of Galileo together it becomes clear that the link between them is circularity. In three dimensional space, the circle is both the plan and elevation of a sphere, the eternal geometry of planets and galaxies. The plan and elevation of planet Earth are the equator and the Greenwich meridian. On a two dimensional plane, the circle revolving around its axis on paper, parchment or plaster is the foundation and boundary of the constructions that can be built within it, some of which as Galileo said, are triangles, squares and rectangles and, *as I say*, the arcing petals of the daisy wheel. Returning to the symbiotic relationship between circularity and angularity we become aware of a second symbiosis between the geometries of heaven and Earth and the fact that the image of the circle embodies a number of different meanings. To an astronomer the circle can be the form of the Sun, Moon or planets, in religious thought the circle can be a halo, the radiant circle of light surrounding the head of saint and to a carpenter or mason the circle represents the first step in the construction of a design. So, although the circle embodies many different meanings depending on the standpoint of the viewer, the clearest view is always that of the people who actually used the tools, compass, dividers, straight edge and square, in their working life. Geometry became the spatial design language of choice because it brought order to a process that was otherwise chaotic. It eliminated guesswork and brought certainty, and this enabled the carpenter or mason to control the proportional relationships of their work.

A daisy wheel scribed into the fabric of a building embodies all of this invisible knowledge and experience in symbolic form and can be seen as a carpenter's or mason's design signature. Apotropaic attributions without knowledge, reason or proof only draw a veil across our eyes. As Galileo directs, if we take the trouble to learn the universal language of geometry we can read what it has to say and, *as I say*, what appears to some observers to be predetermined or meaningless often turns out, in translation, to be poetry.

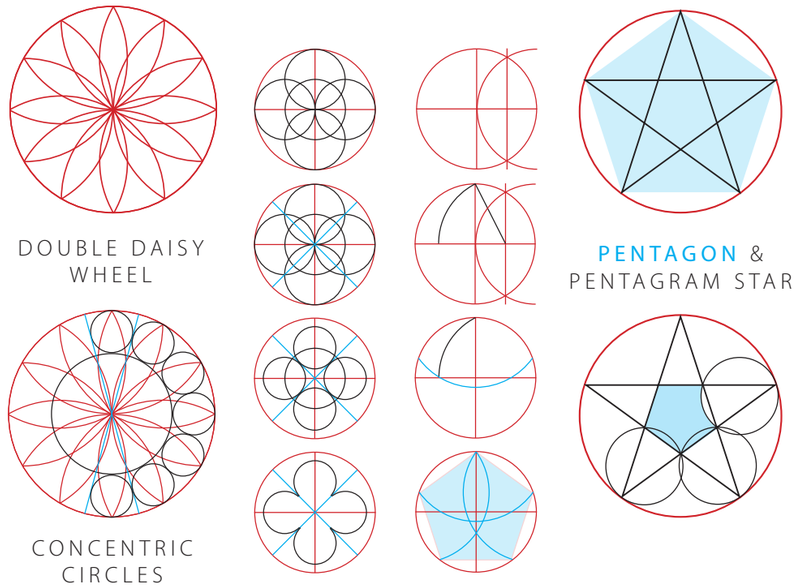
Back down to earth

The last time Richard, Chris and I met at Hayne was in the winter, frozen by an east wind and lashed by sleet. Warming ourselves by the stove in Richard's wooden hut, he raised our spirits with hot soup, pasties, crisps and cake while we discussed our next step. Richard and Chris made it very clear, democratically in a vote of 2 to 1, they thought it was my task, as the geometer, to write up the project. Now, just when Spring *is acumin in,* coronavirus is everywhere and the country is in lockdown. Solitude is not everyone's preference but it is fertile ground for thinking and writing and I take solace from it.

Running through the pages to review the barn's divider-scribed content I realize there is a geometrical archetype missing from the barn's repertoire[18]. The daisy wheel and 5 circle archetypes are there in numbers but there is no evidence of pentagonal geometry. The grand example is Exeter Cathedral's western facade rose window which was designed using double daisy wheel, 5 circle, pentagon and pentagram star geometries. The design of the rose window begins with a double daisy wheel that divides the circumference into twelve equal sectors, an archetype divider-scribed into the barn's walls.

Drawing 64 shows the development of the Exeter rose window. The left hand column demonstrates how the double daisy wheel (scribed at Hayne), divides the circumference into twelve equal sectors and below, how crossed full diameters define the small diameters of the ring of twelve perimeter circles. The second column, top to bottom, shows the construction of a quatrefoil from 5 circle geometry. The third column, top to bottom, shows the construction of an UP pentagon and the right column shows how a pentagram star results from linking the pentagon's angles. Finally, compass arcs define the boundary of the Cathedral's central rose curved DOWN pentagon.

64



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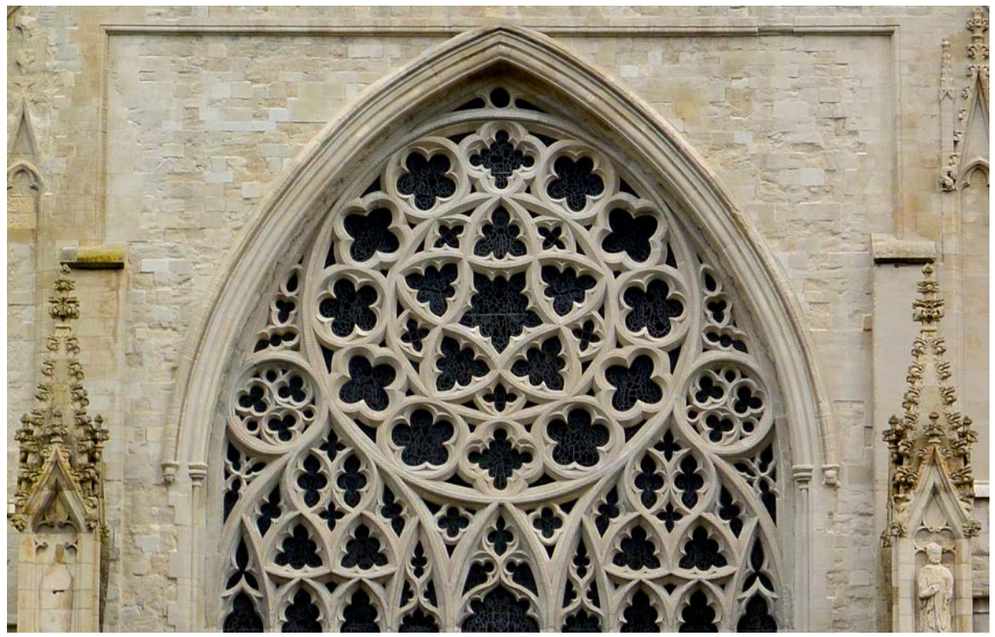

The link between the design of Exeter Cathedral's western facade rose window and the double daisy wheels divider-scribed into the barn walls at Hayne revealed the archetype's survival over a long period. But it existed almost two millenia before that. Vitruvius described how Greek and Roman amphitheatres both originated from twelve equidistant points around the circumference of a circle, the Greek theatre linking the points as three squares and the Roman theatre linking the points as four equilateral triangles. The four sides of three squares (4 x 3 = 12) and three sides of four equilaterals (3 x 4 = 12) are identical around the circumference but generate different auditorium seating alignments and stage settings in the amphitheatres. The geometry also gives us the twelve hours around a clock face.

Pure and simple

After recognising that the pentagon was missing from the barn's walls and that it had, nonetheless, something to reveal, I realised that we had only focussed on what was visibly obvious. The barn's walls were so comprehensively covered in divider-scribed geometrial symbols that it was easy to overlook what was *not* scribed. For example, apart from the two signature identifications WILL and TH there were no other examples of text. No names, no slogans, no religious verses, no handwriting and therefore no evidence of pencils, felt tip pens or any modern aerosol sprayed tags of someone's initials. There were no dates so the nearest clue to a build date was the 1842 tithe map showing the barn in its farm location. There were no drawings such as the house gables (sometimes enclosing initials or dates), no windmills or ships like those found scribed into some church walls, no heraldic shields, no animal, figure or portrait drawings. There were no footprints of square toed shoes like the ones I had observed sixty years ago[19] scored around the wearer's boots into the lead roof of Lighthorne church tower in Warwickshire. There was no evidence of colour, no sign of charcoal, ochre or paint. There were no religious symbols such as the cross and no conventional apotropaic signs such as VV (Virgin of Virgins), AM (Ave Maria) or M (Mary) marks though the meaning of these is a matter of current academic debate. In the absence of all the above, the symbols scribed into the carte blanche of the barn's freshly plastered walls were geometrical, pure and simple. There was nothing else.

So what can be made of these divider-scribed geometries? First we can consider the dividers which were the working tools of carpenters and masons, used at all stages of their work from initial design, stepping out along snapped chalk lines to full scale and, finally, marking out fine detail ready for cutting. Second we can consider the scribing, some of which was clearly carried out by men with geometrical knowledge who carefully scribed several geometrical archetypes high on the walls. Third we must consider the archetypes and what their function or functions might be and here there may be two potentials. The first, referring back to Ian Mock's comments, was that the symbols encouraged fecundity and the second, and this is my view as a geometer, is that they demonstrated the fundamental elements of geometry as a spatial design language and that they include the daisy wheel, 5 circle geometry and circle chain archetypes. And fourth, it can be demonstrated that these geometries generate the barn's proportions. It may be that the symbols represent both Ian Mock's and my point of view and though it is easy to prove the design link between symbols and the proportions of the

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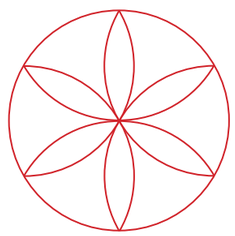
barn it leaves a question in the air as to why geometrical symbols should be seen to support fecundity or to have other meanings as well. And this is where Galileo comes on stage, teaching that geometry is the language of the universe, that the language is mathematical and composed of triangles, circles and other geometrical figures, some of which are the very geometries divider-scribed into plaster on the barn's wall. And Galileo's celestial support act is William Blake whose paintings show God creating the world, dividers in hand. The link between the heavenly and Earthly is clear, that geometry, as the spatial design language of the universe, can be taught to, and illuminate the minds of craftsmen and designers and it is this divine knowledge that brings the same aesthetic resolution to their work as that found in the natural beauty of plants and flowers. As a geometer I recognise the spiritual presence in the way geometry works. It is one of the invisible forces in the world, along with gravity, magnetism, radiation and electricity. We can see the apple fall, the iron filings form their pattern, the Xray's skeletal revelations and the light appearing at the touch of a switch but, though we cannot see the forces themselves, we have learned to tap each of them for our own benefit. So geometry, as we understand it at the drawing board or on the tracing floor, allows us to harness the forces of universal order and place them at the heart of our work.

So what was happening at Hayne when the freshly plastered hay barn walls were scribed? I think it was a multi-faceted event with several aims. It was clearly arranged that geometrical symbols would be divider-scribed and it is clear that the best were scribed high on the walls. These may have had the purpose of encouraging fecundity on the farm but, in my view, were also high so that they could be seen as exemplars. The huge numbers of symbols scribed below the best reveal that others were trying their hand under instruction, attempting to replicate the best examples, and that some were more adept than others. Many of the lower symbols overlap each other and many are incomplete. Having taught geometrical design for the Oak Frame Training Forum apprentices (at Chelvey Court and Chelvey Oak Farm, near Bristol) using an 8 by 4 feet horizontal blackboard and a school chalk compass I recognise how the board begins with clarity and gradually, through discussion, demonstrations and trials, becomes a complex interweaving of arcs and lines, redolent of a tracing floor and similar in spirit to the barn's walls. So I recognise at Hayne the characteristics of a geometry school where the barn's builders, masons, carpenters, plasterers and thatchers, their apprentices, the farm household including children and farm labourers all watched as the fundamental geometrical constructions were scribed and then took their individual turns in a communal celebration that lasted all day. When the scribing was over and every individual mind's eye held a symbol of its own, a farmhouse feast and cider was laid out on trestles in the barn for all. And it was, as they say in Devon, a proper job.



Footnotes

1 The GPS reference is omitted to protect privacy.
2 The authors of *The Three Hares : A Curiosity Worth Regarding* were Tom Greeves, Sue Andrew and Chris Chapman. The editor was Richard Westcott, Richard Wescott and Laurie Smith collaborated on chapter 14, titled *The Measure of All Things*.
3 The floor plan is 56½ feet long at ground level.
4 The vesica piscis term sac is like a small balloon expanded by air pressure.
5 The rectangular cartouche is also geometrically proportioned. It is not shown but it's formative geometry is a double daisy wheel chain.
6 The geometrical analysis of Tŷ Mawr is given in full in the special Millenium 2000 publication *Tŷ Mawr, Castle Caereinion* by the Powysland Club's Montgomeryshire Collections Volume 89 (2001) ISSN 0144 - 0071.
7 The circle geometry shows 11 x 5 feet = 55 feet. This is the wall plate dimension. The length at ground level is 56½ feet so there is a slight taper in the cob from the top of the sill to the wall plate.
8 The drawing shows laths but the geometry could be attained with cords.
9 For those brought up with metric dimensions, fractions are foreign but think of an apple halved, halved again into quarters, the quarters halved into eighths and so on. The fractions given on the page are the numerical equivalent to this simple principal applied to numbers.
10 Patrick Stow's book, *Conservation Engineering - A Collection of Casework* ISBN 978-1-9161579-0-3 is a massive and fascinating study. In Appendix 3 pages 7 and 8 it shows downloads from Laurie Smith's website detailing Medieval Circle Geometry, *Finding and Recording Symbols*.
11 Richard's story is taken verbatim from email correspondence on this topic.
12 Ian Laing and Richard Grigson are the owners of The Reader's House.
13 I took this photograph when I visited The Reader's House during Simon Buteux's ownership.
14 The measured elevation, drawing 56, was made available by Simon Buteux.
15 Duncan and I have both given presentations on aspects of historic building design at Vernacular Architecture Group, Carpenters' Fellowship Frame Conferences and elsewhere.
16 A simple visual test for the proportions of the Durham cylindrical columns is to roll an exact square of firm paper into a cylinder and tape the join.
17 Mathes Roriczer's and Hanns Schmuttermayer's booklets mark a major and highly inventive development in architectural geometry beyond the then prevailing use of compass geometry (source of the Romanesque half round arch and the Gothic pointed arch) but as Hanns Schmuttermayer stresses in his introduction, square geometry arises from compass geometry, and more specifically from the axis of a circle.
18 As humans we give credence to mass over space and to solids over voids and see buildings as solid structures rather than encompassed spaces. Sometimes it is useful to look through the opposite end of the telescope which, as a microscope, reveals new insights.
19 In 1957 I was serving in the Royal Air Force at RAF Gaydon in Warwickshire where I maintained radar sets on Victor nuclear bombers. At weekends I escaped into the surrounding countryside and in the village of Lighthorne I climbed the bell tower for the view and found the scribed footprints.

Photo credits

Chris Chapman Front cover Introduction 3 4 6 7 11 12 13 16 17 23 24 25 33 40 45 46 47 48 49 52 53 54 Rear cover
Laurie Smith and Richard Westcott portrait, page 57
Laurie Smith 8 23 41 55 61 65
Richard Westcott 1 2 Chris Chapman portrait, page 57
Clwyd Powis Archaeological Trust 30 (video scan of symbol)
Duncan James 58

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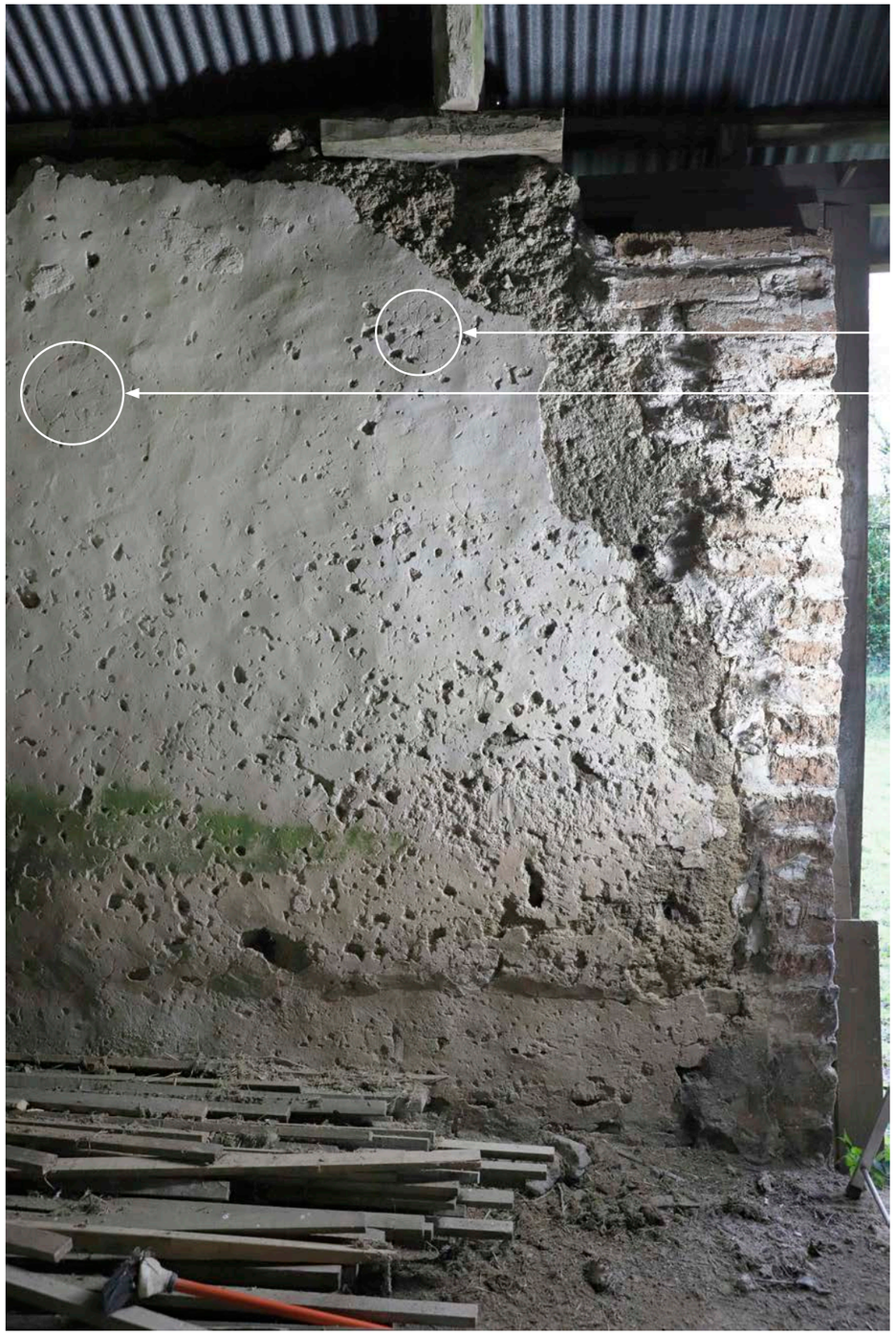
The TEAM

Laurie Smith, above left, studied ceramics at the Central School of Art and Design in London. He taught Ceramics on degree courses at Loughborough College of Art and Design and at Leicester Polytechnic, both in Leicestershire, for 20 years. His writing on geometrical design systems features in a number of books including – ***Useful Geometries for Carpenters*** in Timber Framing Fundamentals: Timber Framers Guild, USA, 2011. ***Following the Geometrical Design Path from Ely to Jamestown, Virginia*** in Built from Below: British Architecture and the Vernacular, Routledge 2011. ***The Geometrical Design of Saint David's Cathedral Nave Ceiling,*** published in conjunction with the UK Carpenters' Fellowship, 2017. Additionally, 40 geometrical design articles are available as free downloads from his website www.historicbuildinggeometry.uk

Richard Westcott, above right, spent his professional lifetime as an NHS GP in a North Devon market town and now has the time to concentrate on his writing, which has won a variety of prizes and commendations. His first well-received poetry book ***There they live much longer*** draws on his medical experience, and is featured at www.indigodreams.co.uk/richard-westcott/4594230918
He blogs at www.richardwestcottspoetry.com and has worked on several books with photographer Chris Chapman, including the highly acclaimed ***The Three Hares, A Curiosity Worth Regarding*** (now sold-out), to which Laurie Smith contributed a chapter which includes an introduction to the Daisy Wheel symbol. Richard is never happier than working on the land in which the barn in question is the centre-piece.

Chris Chapman, below, was brought up on the edge of the Pennines in Lancashire and began his photographic career in 1974 at the Newport College of Art in South Wales where he was invited to join the Documentary Photography Course run by the Magnum photographer, David Hurn. In 1975 Chris moved to Dartmoor, Devon, since when he has documented life on the moor. He has a large archive depicting the culture and character of the region. His photography has been widely recognised and is represented in collections of the Victoria & Albert Museum, Arts Council England, the International Center of Photography, New York and in numerous private collections. His work has been published under various titles – ***Wild Goose & Riddon***. ***The Dartmoor Photographs of Chris Chapman*** (Halsgrove 2000) and ***Silence at Ramscliffe: Foot & Mouth in Devon*** (The Bardwell Press 2005, Oxford).



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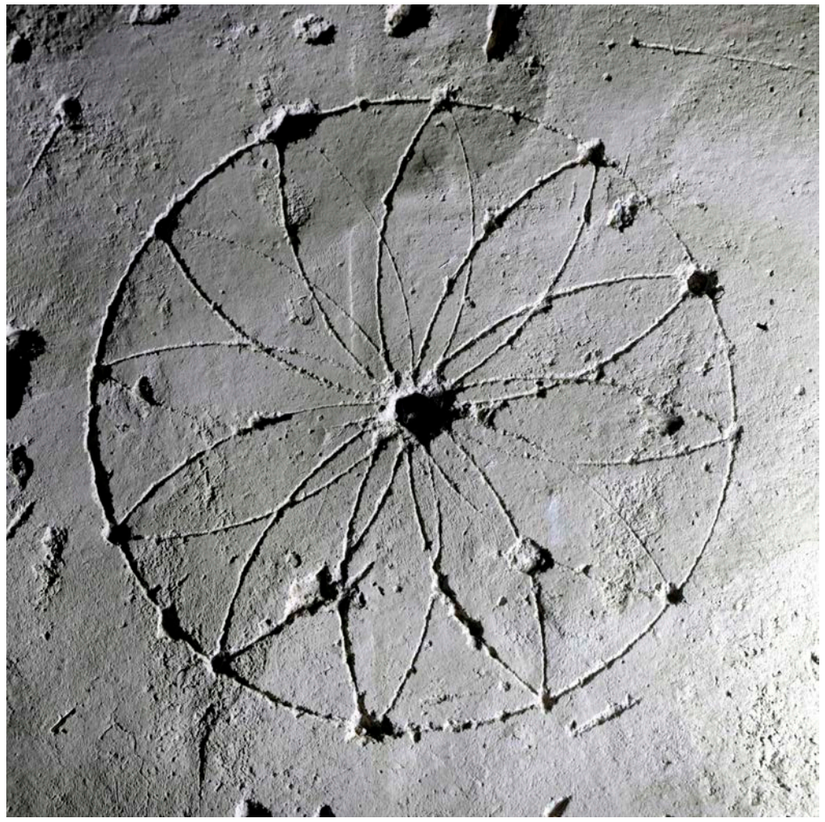


APPENDIX

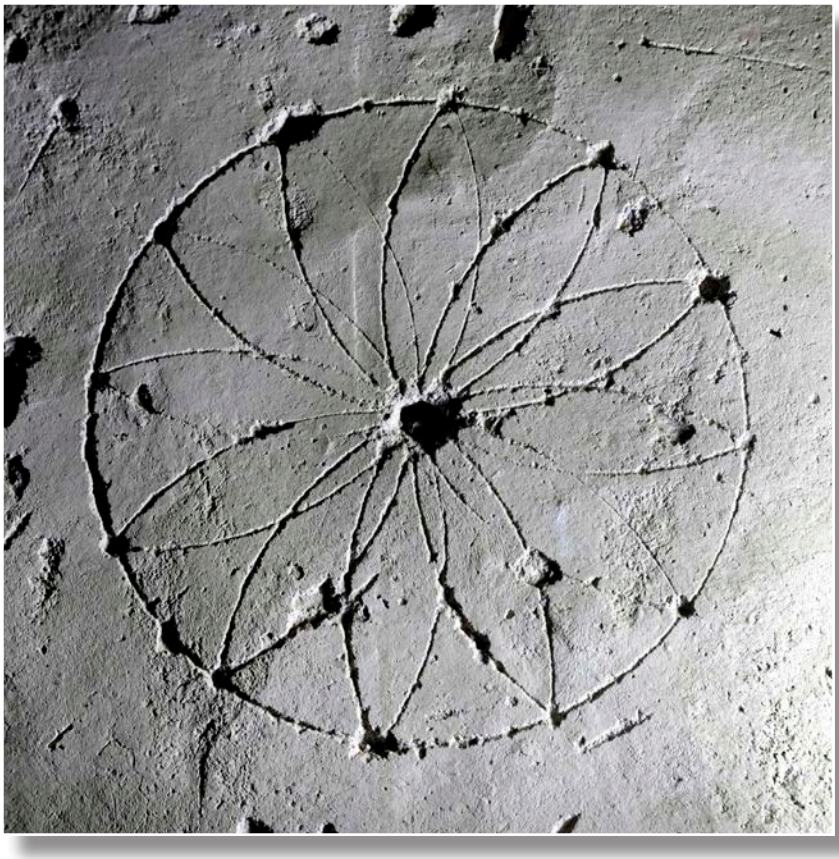
Opposite and above

Chris Chapman's photographs capturing the location and detail of two double daisy wheels. The wheel shown above is on the far left of the main photograph and was re-photographed in raking light. The image shows the geometrical precision of the divider-scribing, the scars of the divider pin at the twelve points around the primary circle and the compound damage caused at the symbol's axis by the passing of twenty four arcs.

Overleaf

Laurie Smith's photograph of a set of his dividers. They are around a hundred years old and are made of cast iron. They are 16½ inches long from the axis head to the tip of the pins, exactly 1:12 ratio to the medieval Rod of 16½ feet. The shadow reveals the heart shape of the locking screw handle.

ISBN 978-0-9932286-1-2



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