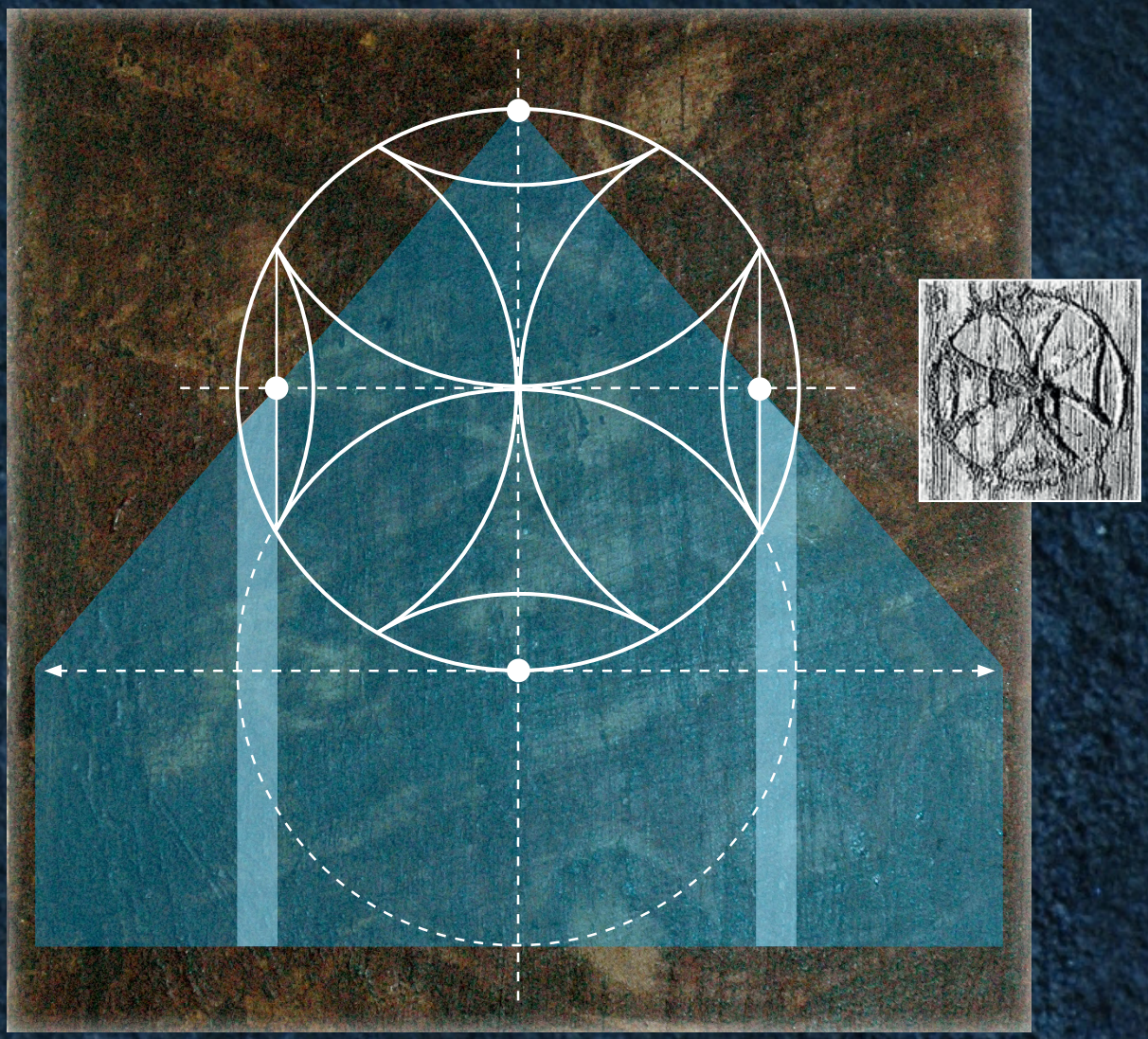
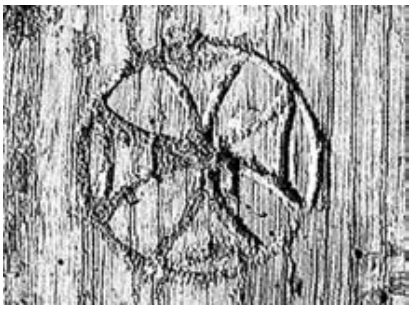
Geometrical Design in Historic Welsh Frames



Laurie SMITH
HISTORICBUILDINGGEOMETRY

Geometrical Design in

Historic Welsh Frames



By permission of the Powysland Club

HISTORIC
BUILDING
GEOMETRY

Laurie
SMITH

This article was first published in
TIMBER FRAMING
the Journal of the Timber Framers Guild, USA
(Volume 70, 2003, ISSN 0305-5477).
It presents geometrical analysis and findings
from three early buildings erected in eastern Wales
between the 15th and 17th centuries –

All are box-framed hall houses. The text describes the geometrical symbols discovered in the houses and the design systems that arise from them.

This **e**DITION 2016 includes additional new material.

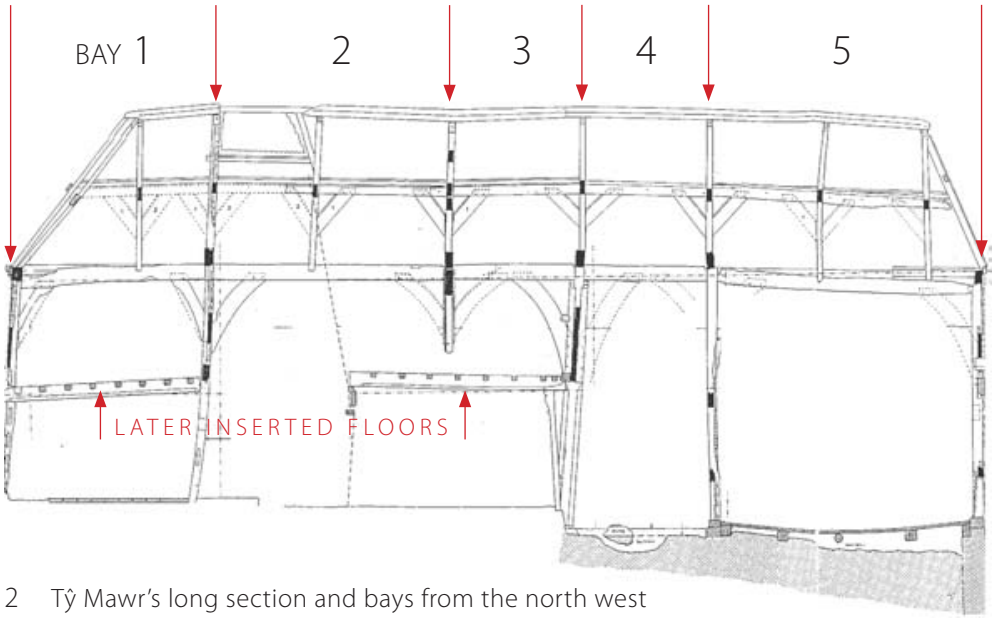
TŶ MAWR,
Castell Caereinion, Montgomeryshire

TŶ MAWR, *The Great House*, was built in open countryside five miles west of Welshpool, the nearest large town, and ten miles west of the English border in the old county of Montgomeryshire, now absorbed into the modern county of Powys. Although English has encroached, the beauty of the Welsh language survives strongly in the names of houses and farms. Tŷ mawr has neighbours called Pant-yr-Alarch, the hollow of the swan, and Allt-y-ceiliog, the steep hillside of the cockerel. The siting of the house, like that of most early Welsh houses, is weather and light specific. Built on a north-south axis with gable end into the southern flank of a steep hillside, figure 1.

1 Tŷ Mawr from the south east

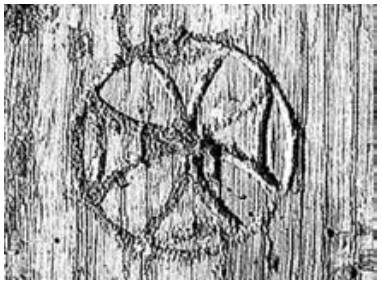
The house is protected from northerly winter weather blowing down from the Berwyn mountains, while the eastern and western long walls face the dawn and sunset respectively so that the house receives maximum light. The frame is constructed on an artificial horizontal platform contained within raised stone plinths that support the oak frame, the plinth being shallow at the northern, uphill gable and around 6 ft. high beneath the southern, downhill gable. In an area of high rainfall, the siting of the house at 90 degrees to the hillside directs surface water past the long side walls and away from the southern gable. Conversely, the northern gable bears the brunt of downhill surface runoff. As its name implies, the house is large, 25 ft. to the ridge and about 58 ft. long by 28 ft. wide in plan, a building of 5 bays in the typical three-unit plan of the area.

Bay 1, the first or service unit, at the northern end, is an inner room for preparation of food. Bays 2, 3 and 4 form the second unit, a large central hall. Bay 4 is a cross-passage with outside doors to the east and west. The cross-passage defines the southern end of the hall and separates it from bay 5, the third unit, often a parlour but also known as the outer room, figure 2.



2 Tŷ Mawr's long section and bays from the north west

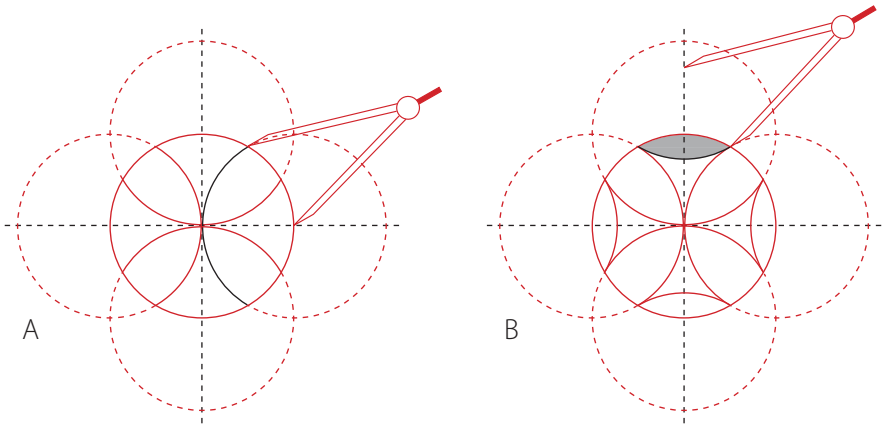
The house is a box framed aisled hall with a single base cruck spanning the hall between bays 2 and 3. (In box framing, the walls rise vertically from sill to wall plate and tie beam in the form of a box. In cruck framing, full cruck blades standing as principals rise inclined from sill to ridge. Base crucks rise vertically from sill to wall plate and then follow the roof plane to the collar.) Tŷ-mawr is listed Grade I by CADW Welsh Historic Monuments and has been dendrochronologically dated to 1460 by The Royal Commission on the Ancient and Historical Monuments of Wales (RCAHMW). Although the house was clearly of significant social status, its builder remains unknown. It is over 35 years since Peter Smith, author of the definitive *Houses of the Welsh Countryside* (London, 1975), and Cecil Vaughan Owen, his friend and co-researcher, discovered Tŷ-mawr derelict, clad in corrugated iron and used as a cowshed, its fall from grace complete. The iron cladding clearly saved the core of the frame, but the long outer aisle walls were long gone and had been reconstructed at some unknown time closer to the nave of the house. Built into the hill, the northern gable had almost collapsed but, as the building's recording began, a small geometrical symbol was found carved into the *inner face* of the gable's eastern aisle post, figure 3. It was clearly not an assembly mark because, in timber framing, assembly marks are always scribed or cut into the *outer faces* of external walls.



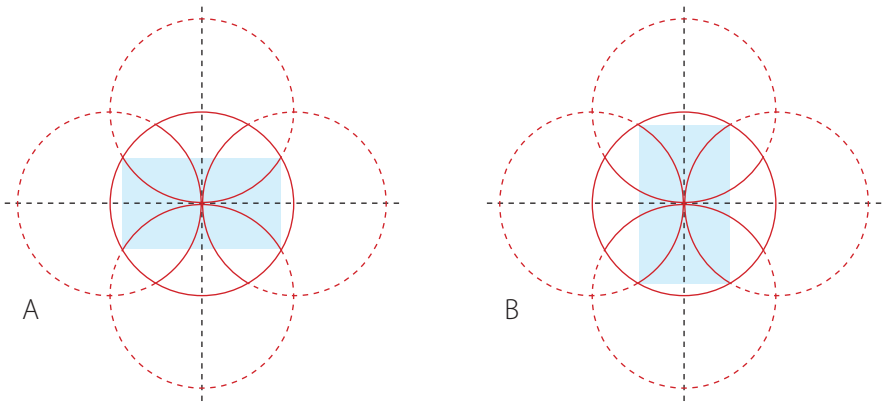
3 Video still of Tŷ Mawr's geometrical symbol

The symbol is critical to an understanding of Tŷ-mawr's design. In the following text, its geometrical construction is first clarified, then applied as an analytical tool to some of the measured drawings of the house and, finally, used to reconstruct the building's design. The symbol's geometry is constructed entirely from arcs of circles: a complete primary circle, four long arcs that span its diameter and four short arcs linking the ends of the long arcs where they meet the primary circle's circumference. Though the diameter of the primary circle is just 2 1/16 inches, it is clear beyond doubt that the symbol represents a symmetrical grouping of compass drawn arcs. In redrawing the symbol, horizontal and vertical perpendiculars are drawn first, and these are the bedrock of its symmetry. The primary circle is drawn with its axis at the intersection of the perpendiculars. Each long arc is part of a full circle drawn from a point of intersection between the primary circle's circumference and a perpendicular, figure 4a. The short arcs follow, drawn from four new points on the perpendiculars, found by placing one pin of the dividers at the end of a long arc and the other on the perpendicular, figure 4b. Because every arc of circle is drawn to an identical radius, the short arcs form symmetrical mirror images of the primary circle's circumference to generate a small vesica piscis between each pair of long arc ends. The upper vesica is shown in dark shading. Approximating the shape of a fish, it was the earliest Christian symbol.

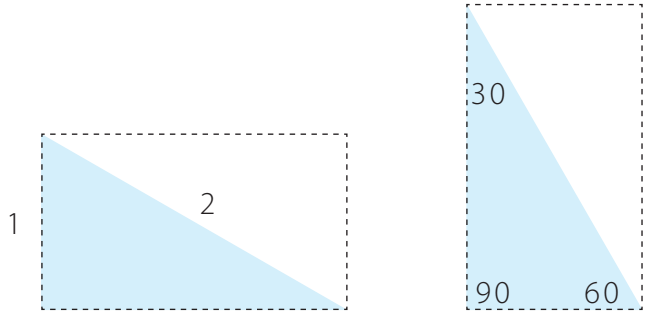
Constructed from nine identical-radius arcs of circle, each with its axis on either the horizontal or vertical perpendicular, the symbol is symmetrical in four directions that are at right angles to each other. The symbol is therefore, perhaps unexpectedly to the modern eye, a source of rectangular proportional relationships. Connection of adjacent long arc ends generates a horizontal rectangle, figure 5a, and vertical rectangle, figure 5b.



4 Construction of the symbol's long and short arcs

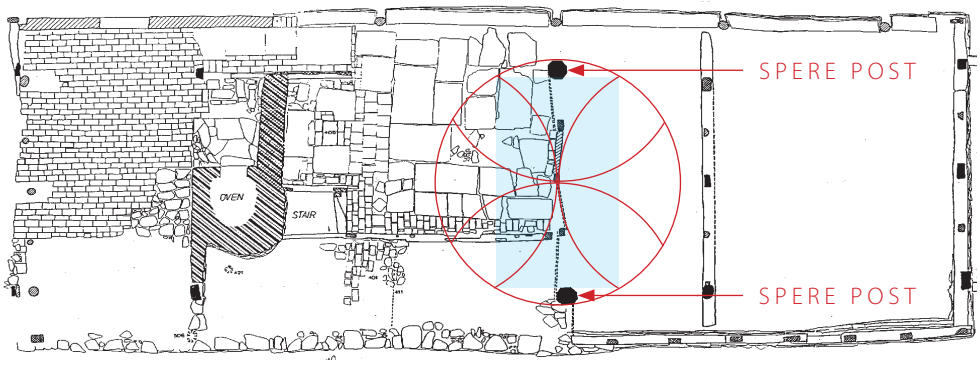


5 Construction of the symbol's horizontal and vertical rectangles



6 Proportional ratio and angles

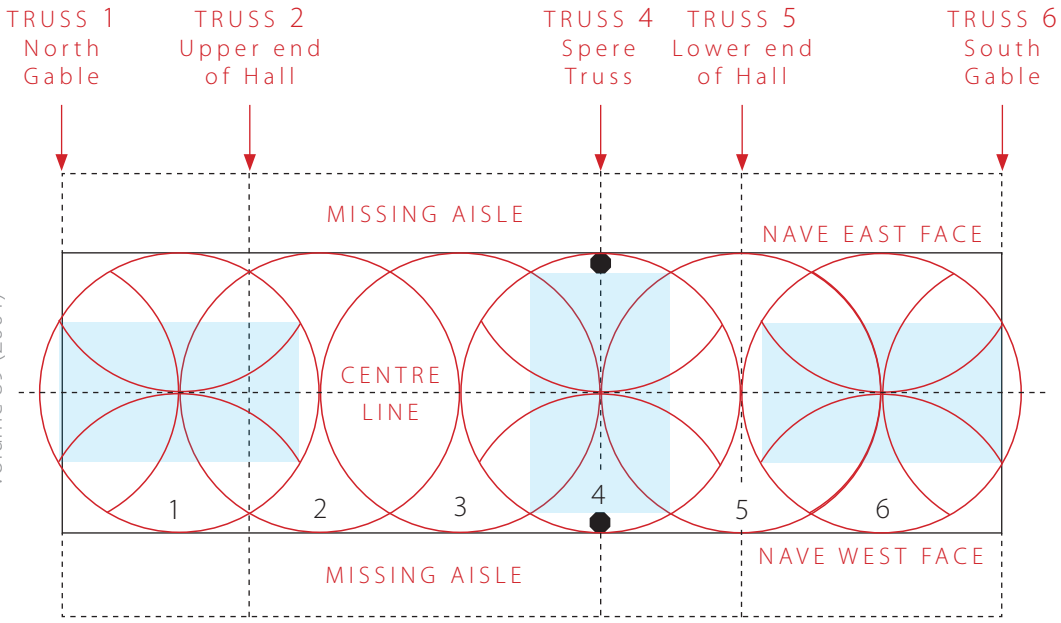
The rectangles have identical proportions and share the harmonic ratio of 1:2 between their short side and diagonal. They are also an accurate source of 30, 60 and 90 degree angles, figure 6. It should be noted that the precise and elegant proportions of the rectangle are difficult to draw in any other way than by circle geometry. Circle and arcs can be drawn swiftly by compass and connected by straight edge. Critically, the rectangles are proportional rather than dimensional, and no measurement or calculation is needed in their construction. Drawing the symbol at any scale, the only dimension necessary is the radius of the primary circle. At Tŷ-mawr the primary circle radius is 8 ft. 3 in., the diameter 16 ft. 6 in., exactly one medieval rod (also pole or perch), a measure seldom used today. With the symbol's construction certain, it became possible to apply its geometry to the measured floor plan of the building in search of potential synchronicity. Because the symbol itself has precision centre lines in the form of its perpendiculars, the rational first step was to draw a centreline through the long axis of the floor. Bearing in mind the nature of aisled construction as a nave flanked on each side by an aisle, and also that the original aisle walls were missing, the centreline could only be ascertained from the surviving nave alignments. The nave's length, width and height had survived remarkably intact within the hall, the central and most protected part of the house. Although the hall's base cruck had lost its blades along with the original aisle walls, its upper structure remained, supported between the arcade plates and the ridge. Conversely, the spere truss between the cross-passage and the hall retained its original form and was in remarkable condition for its 540-year life. (In aisled halls, the spere truss defines the lower end of the hall. It always includes two spere posts which, archbraced to a tie beam, stand at the outer edges of the nave to form a grand entrance arch to the hall proper.) The spere truss therefore provided the optimum location along the centerline to test the symbol at full nave width. It was immediately evident that the spaces between the rectangle's short sides and the primary circle were occupied by the feet of the spere truss posts, the outer face of the posts defining the outer face of the nave on the circle's circumference, figure 7.



By permission of the Powysland Club

7 The symbol synchronised to the spere posts

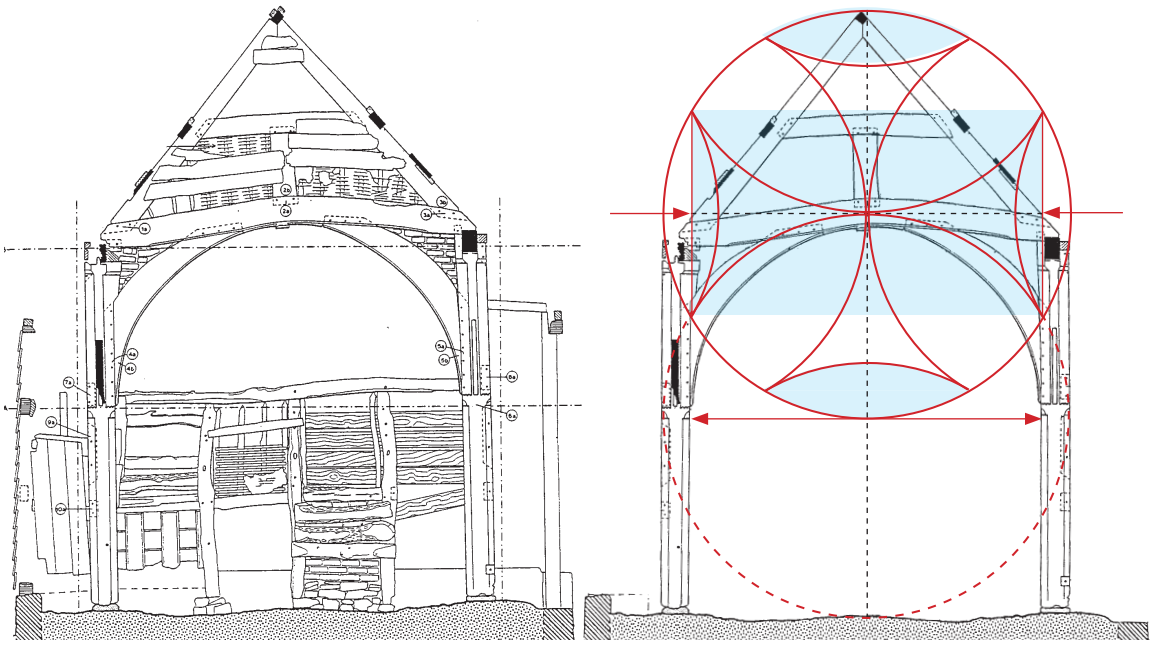
Multiplying the symbol along the centre line also gave precision results, the nave being defined by a six-circle sequence with horizontal rectangles in the end circles pinpointing the gable walls across their short sides, figure 8. For clarity, the floor sequence is shown as a diagram. From the six-circle sequence it was possible to determine exact geometrical locations for five of the six cross-walls of the house. The only omission was the base cruck that originally rose from the missing aisle outer walls, an alignment that remained enigmatic. It can be seen in figure 8 that truss 2 is located at the intersection of circles 1 and 2 where it bisects the vesica formed by them. Truss 5 is the diameter of circle 5. The symbol is drawn only in the circles at the spere truss and the gable ends. These are the only places where it is necessary as a precision geometrical guide, and this fact begins to reveal the nature of geometrical thought that underlies the design of the house. The fundamental spatial rhythm of the nave is determined by the circle sequence, each circle drawn to pass through the axis of its neighbours, along a common centre line, every circle to identical radius. The symbol, developed geometrically within any circle, provides the potential for finer resolution of the design, every facet of which is aesthetically anchored within the circle sequence. The other characteristic of note is that the symbol is used in the directions governed by its perpendiculars, so that both the horizontal and vertical rectangles have a role to play in the design.



8 The symbol governing a six-circle sequence

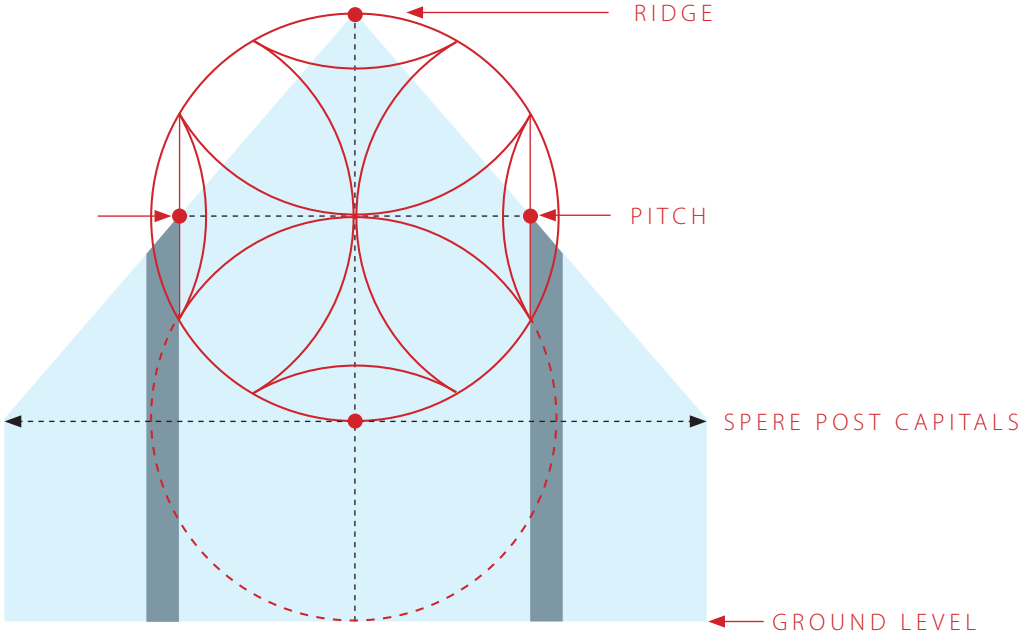
Having found a positive relationship between the symbol and the floor plan, I next tested the symbol against the cross-section of the house, choosing the spere truss because it was the least damaged truss in the frame. The measured drawings of the spere truss show evidence of a later inserted floor and the great arch of the truss itself blocked in order to separate the cross-passage from the hall. On computer, all these accretions were stripped away to reveal the truss as built. The symbol was applied at identical scale to that on the floor plan and, developed as a two-circle sequence, gave the exact geometrical height of the truss. Of great importance, it was clear that the roof pitch ran precisely through the centers of the two vesicas on either side of the symbol and that the apex of the ridge beam was defined by the vesica at the top of the symbol, figure 9.

Montgomeryshire Collections
Volume 89 (2001)



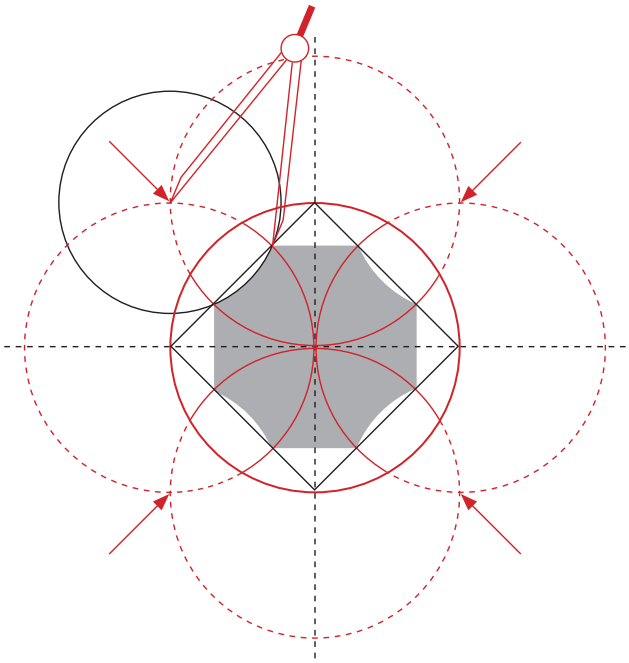
9 The symbol synchronised to the spere truss

The symbol's definition of the roof pitch was a critical discovery in understanding the form of the missing aisles. If the symbol's triangulation is drawn, at the angle of pitch, from the ridge to level with the base of the circle's lower vesica, it generates the location of the eaves and therefore the missing aisle walls. The two-circle sequence demonstrates the four cardinal geometrical points within the symbol that determine the roof pitch. The design logic is clear: the highest point of the top vesica and the lowest point of the bottom vesica define the pitch at one circle's height (or a diameter of 16 ft. 6 in), identical to the nave width across the spere truss at ground level. The spere posts themselves are half the width of the vesicas, exactly the distance between the circle's circumference and the rectangle connecting the long arcs, figure 10.

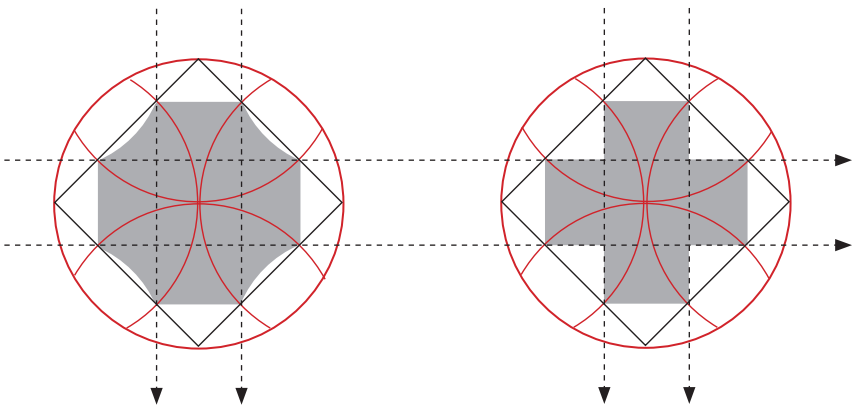


10 Generating the spere posts, level of post capitals and aisle width

The figure also shows how the symbol's base, at the eaves level indicated by the dashed black arrows, also cuts the spere posts to mark a critical change in their section. Rising from the ground as massive octagons, with alternating flat and concave faces (shaded section, figure 11), the posts become cruciform, the four directions forming vertical surfaces for the spring of braces to the aisle outer walls, arcade plates, and high entrance arch across the nave (shaded section, figure 12. The change in section is marked on all sides of the post by a narrow embattled capital. The spere post sections are determined by the symbol. The introduction of a square (set diagonally) into the symbol cuts the long arcs to generate an octagon with sides of equal length, figure11a. The intersections of the long arcs outside the primary circle, shown by an arrow, act as the axes of smaller circles, the circumferences of which define the concave faces of the lower spere post section (for clarity, only one is shown). The cruciform upper spere post section is generated by connection of the intersections between the long arcs and the diamond, figure 12. The spere posts are cut from single timbers, one circle diameter or one rod (16 ft. 6 in.) in length. It is impossible to ignore the pivotal role of the symbol in all of these tests.

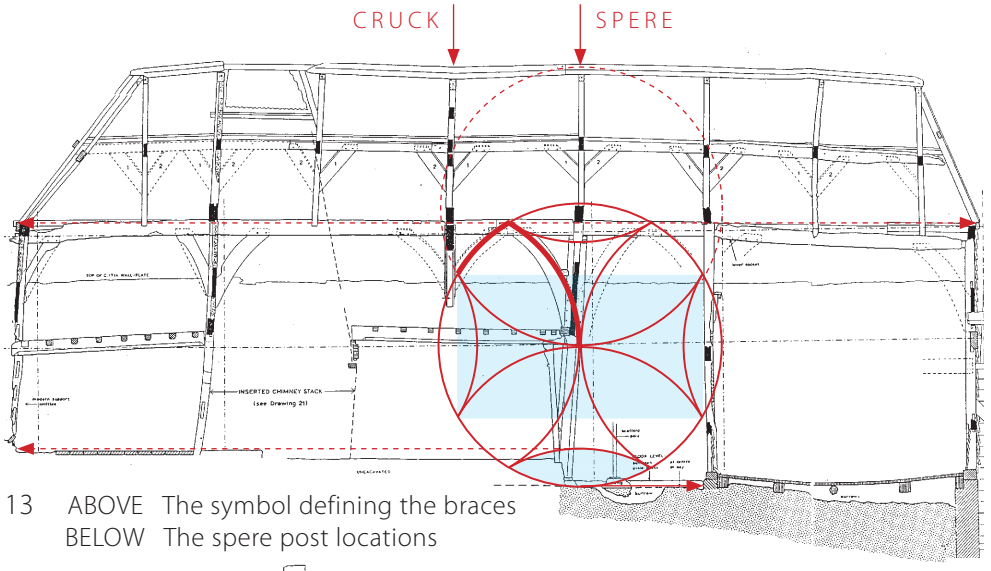


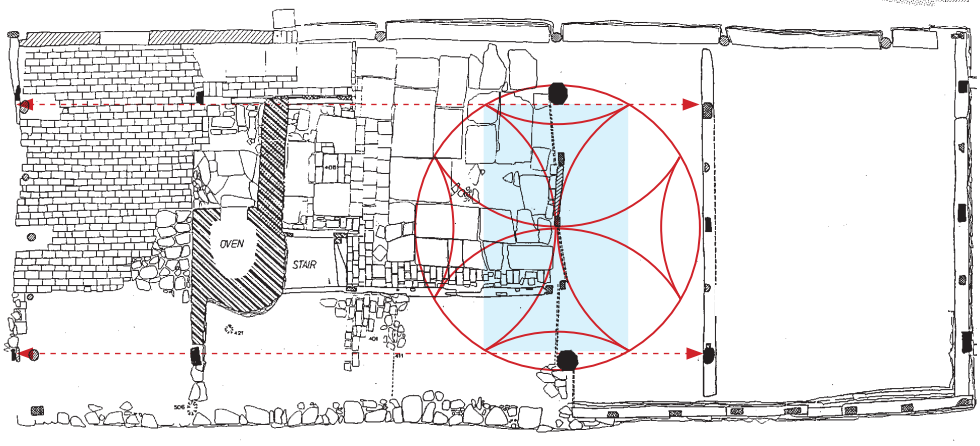
11 The symbol defining the lower octagonal spere post sections



12 The symbol defining the octagonal and cruciform spere post sections

The base cruck truss still remained undefined by the symbol. It was not recorded on the floor plan because its bases at sill level were lost with the original aisle walls, but its upper structure was visible adjacent to the spere truss in the long section (frame elevation) of the house. Testing with the symbol revealed that the cruck's location was also determined by a rectangle within the primary circle. It is noticeable that the spere posts have racked to the right in the upper part of the symbol and to the left in the lower, but remain geometrically accurate at the symbol's centre. The long section and floor plan are compared to show the symbol's function in both the horizontal and vertical planes, figure13. The placement of the symbol in the long section also shows its influence at ground level, where the symbol's bottom vesica stands on the lower floor level of the house and simultaneously defines its higher level at the service end. The symbol also exerts a powerful aesthetic influence on the braces between the spere and cruck trusses: the two surviving original braces, figure 13 upper, unwaveringly follow the geometry of the symbol's arcs. The small cruck brace following the circle's circumference and the long spere post brace rising from the circle's axis meet in a gothic arch at the arcade plate. Figure 13 lower shows the symbol's control of the spere post locations.

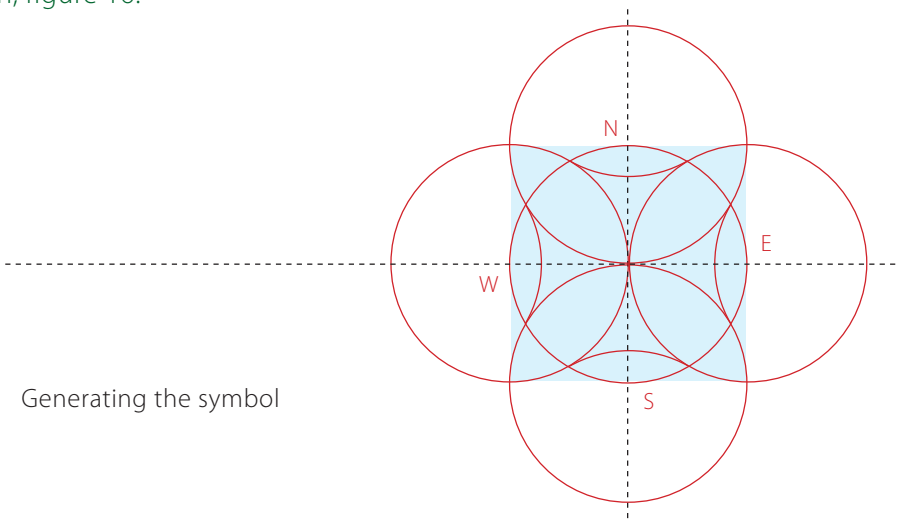




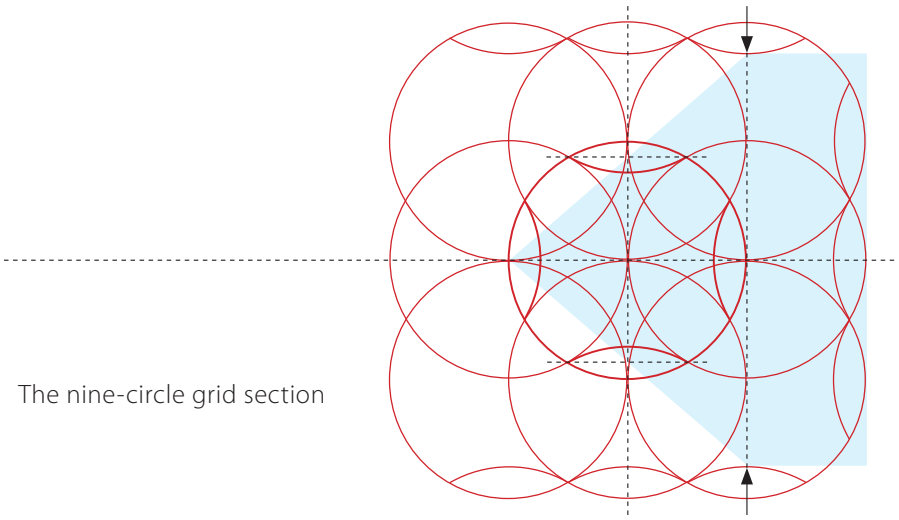
13 ABOVE The symbol defining the braces
BELOW The spere post locations

Reconstruction of Tŷ-mawr's design begins with horizontal and vertical perpendiculars and the primary circle drawn from its axis at their intersection. Where the perpendiculars cut the primary circle at its N, S E and W poles, four identical circles are drawn and automatically generate the symbol. These circles intersect at four positions outside the primary circle that can be connected to form

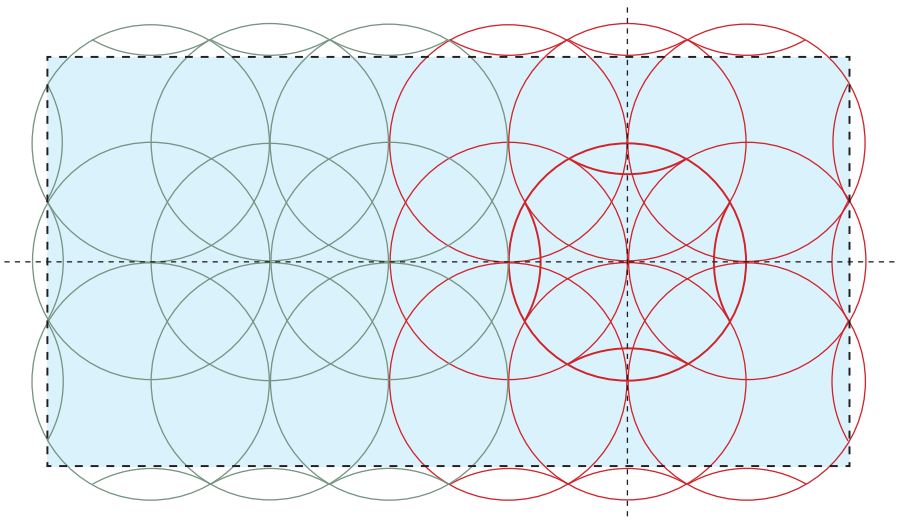
a perfect square, figure 14 (shown in blue tone). Four more identical circles are drawn from the corners of the square to generate a nine-circle grid, figure 15. All six trusses of the house can be designed individually within the nine-circle grid. The nine-circle grid is doubled to form an 18-circle grid, six long by three wide, the vesicas governing cardinal wall alignments in laying out the full floor plan, figure 16.



14 Generating the symbol



15 The nine-circle grid section

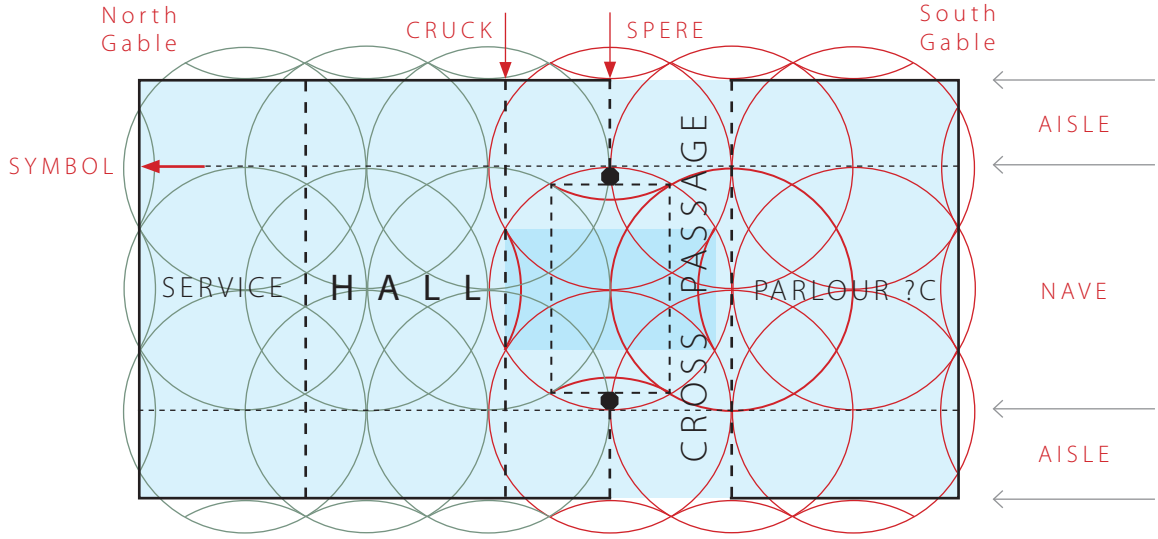


16 The eighteen-circle floor plan

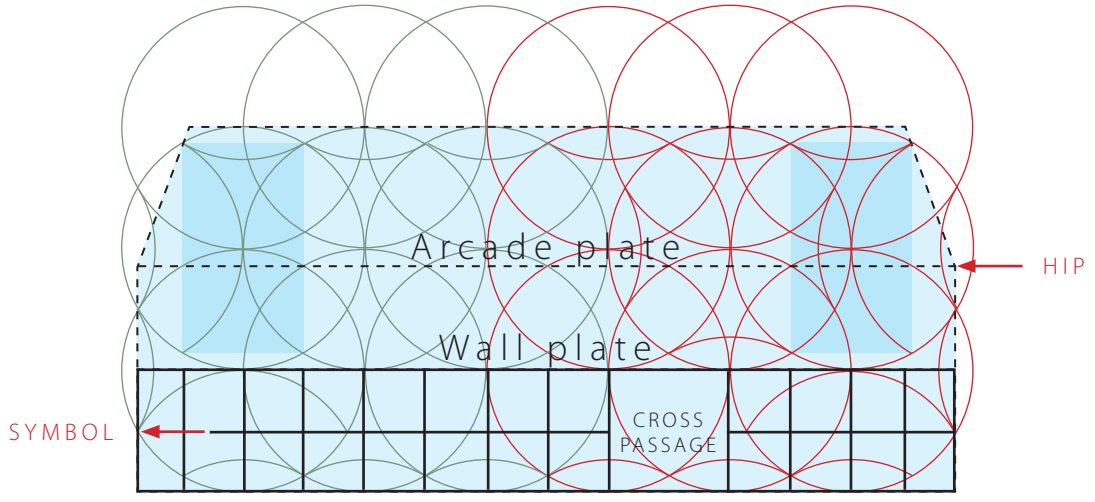
Figure 17 shows how the symbol's vesicas are crucial to the floor plan's boundary: the gable ends bisecting the vesicas and the long walls running as tangents to the vesica's inside edges to define the floor plan outline.

Figure 18 shows the roof above the gable ends in the long section where it can be seen that the vertical rectangles (in darker shading) within the end circles control the pitch of the hipped roof, described by lines drawn between the arcade plate ends and the top outer corners of the rectangles. It is also clear from both drawings that the symbol is carved in a location (marked by red arrowheads) that occupies a specific geometrical position in both the long section and the plan, a placing indicating that the master carpenter was thinking simultaneously in both the horizontal and vertical planes. This indication is borne out by the horizontal and vertical pairs of arcs within the symbol that, when connected, form horizontal and vertical rectangles.

The symbol clearly had a function similar to the use of modern protractors to draw accurate angles, but what the symbol also provided, and protractors do not, was a set of related proportions that governed every element of the building's aesthetic. No wonder it was carved into the frame: a design icon, a master carpenter's signature, whatever you wish to call it, but emphatically a key to unlocking the concepts of 15th-century building design. The tragedy is that during modern repairs this unique symbol was lost, rumoured to have been burnt in a clean-up of timber waste from the house before its official opening by the Prince of Wales.



17 The eighteen-circle floor plan



18 The eighteen-circle long elevation. The frame is two circles in height.

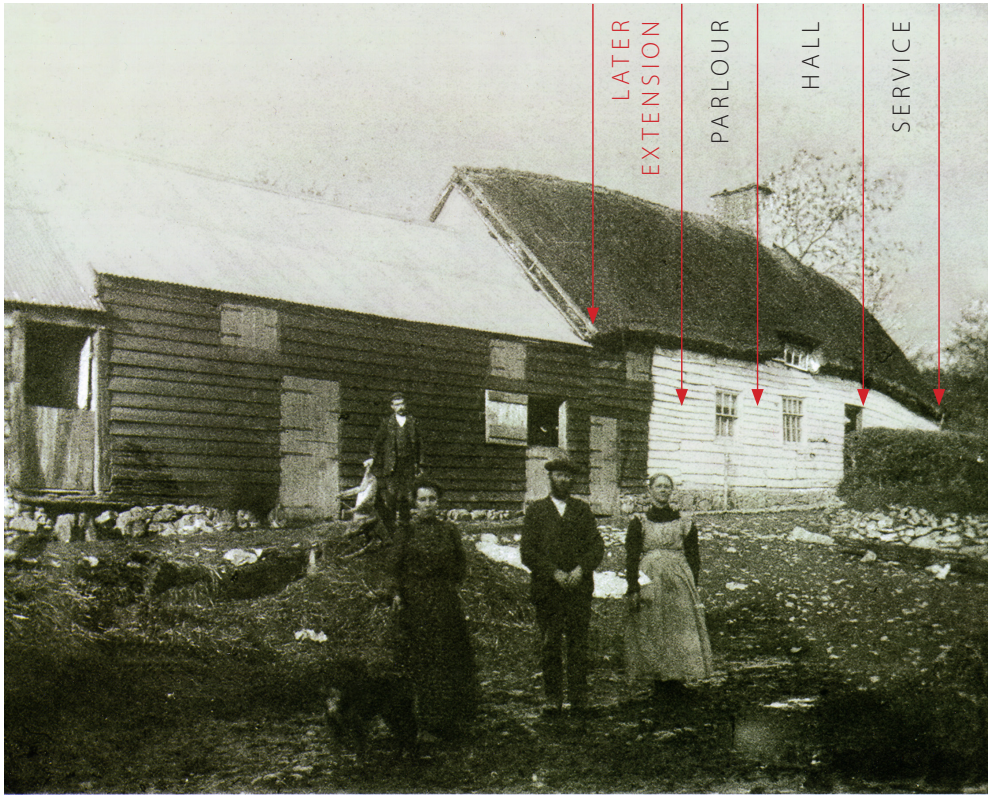
19
20
21
22

19 The south gable
20 The cruck truss apex
21 The western long wall
22 The octagonal spere post crenelated capital

GWERNFYDA

Llanllugan, Montgomeryshire

GWERNFYDA was built in open countryside eight miles west of Tŷ Mawr as the crow flies and occupies a similar site at the foot of a hill, but long-side across the slope. Although this position is less efficient for drainage, it was clearly chosen in relation to shelter and light. The house is well protected from the prevailing south-westerlies and faces south east so that the morning and evening sun illuminate the full length of the house. The Afon Rhiw (mountain river) runs one small meadow away from the house. Drained in modern times, the meadow was once the marsh that gave the house its name. The house has the typical three-unit plan of the locality with a central hall flanked by a parlour at the upper end and a service room at the lower, though, unusually for Wales, it has a narrow bay at the lower end of the hall that functions as a smoke bay or proto-chimney. At the upper end of the hall there is a solid oak post-and-panel wall, showing small mortises where a bench was once fitted to it, and above the now missing bench, a dais canopy. The post-and-panel wall and dais canopy, sited between the ground floor windows, were signs of status, figure 1.



1 Gwernfyda, thatched and limewashed, circa 1900

In earlier hall-houses, the floor was often of packed earth, and a small dais, a platform not unlike those used for a school-teacher's desk, raised the trestle table and bench off the earth at the upper end of the hall. The dais canopy, a narrow ceiling that ran across the width of the hall above the dais, protected those eating at the trestle from the falling soot and smuts that had risen on the heat of the open fire into the roof space before cooling and falling back down. The

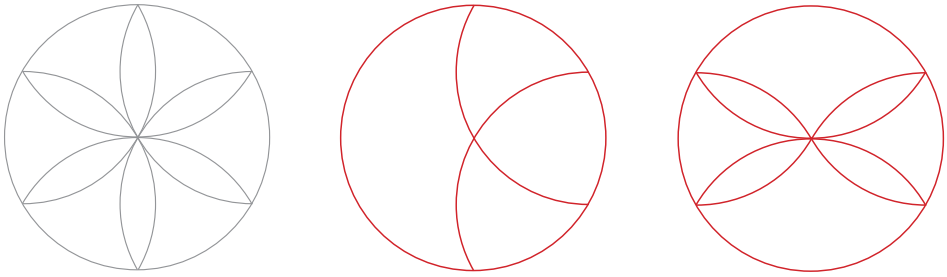
house is entirely box framed in oak on a shallow stone plinth and, though well below the social standing of Tŷ Mawr, was clearly the property of a well-to-do yeoman farmer. For a long period, the house was the property of absentee landlords. Their tenants, farming marginal land, could afford little maintenance and none of the fashionable improvements of their time. The original heavy flag roof had fallen into disrepair and been replaced by thatch before 1900 and by corrugated iron at the outset of World War II in 1939, *the cheap option in case we got bombed,* according to a family descendant.

2 Gwernfyda, repaired, re-slated and re-weatherboarded, 1994

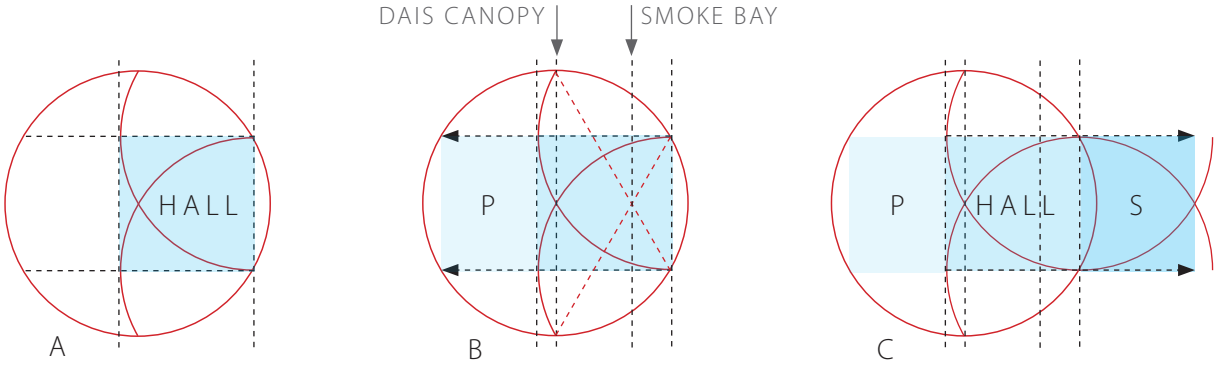
Weather-boarding has preserved the frame since 1900 while the modern 1994 larch boards, figure 2, conceal recycled newsprint insulation ensuring that the house, now cool in summer and warm in winter, will be habitable into the foreseeable future. At some unrecorded time, a fashionably tall stone chimney stack was built inside the smoke bay, incorporating a massive oak lintel carved with two quatrefoils, a phoenix, a running stag and hound, an amphisbaena (double-headed serpent) and a crucifixion, figure 3. The beam, which is not an original part of the frame, is thought to have come from the Cistercian nunnery at Llanllugan, a mile down the valley. At the crossing of the hall ceiling spine beam and transverse beam, there is a boss with the carving of an owl, and the faint ghosts of medieval painting survive on some timbers and the few remaining wattle-and-daub panels within the upper floor of the hall. Gwernfyda is approximately two-thirds of Tŷ Mawr's size, 48 ft. in length by 20 ft. in both width and height. The house was dendrochronologically dated to 1552 by The Royal Commission on the Ancient and Historical Monuments of Wales. The house is listed Grade II star, and its description cites *the rare survival of a medieval house in its original form*. The original owner of the house remains unknown.

There are two geometrical symbols on Gwernfyda's frame. The western gable has an incomplete race-knifed wheel 8¼ inches in diameter, at the centre of lowest tie in the outer face of the southern gable and another incomplete divider-scribed wheel 2$\frac{1}{16}$ inches in diameter, on the lower face of the hall's post-and-panel wall. Like Tŷ-mawr's symbol, neither are assembly marks.

3 Medieval carvings on the inserted fireplace lintel

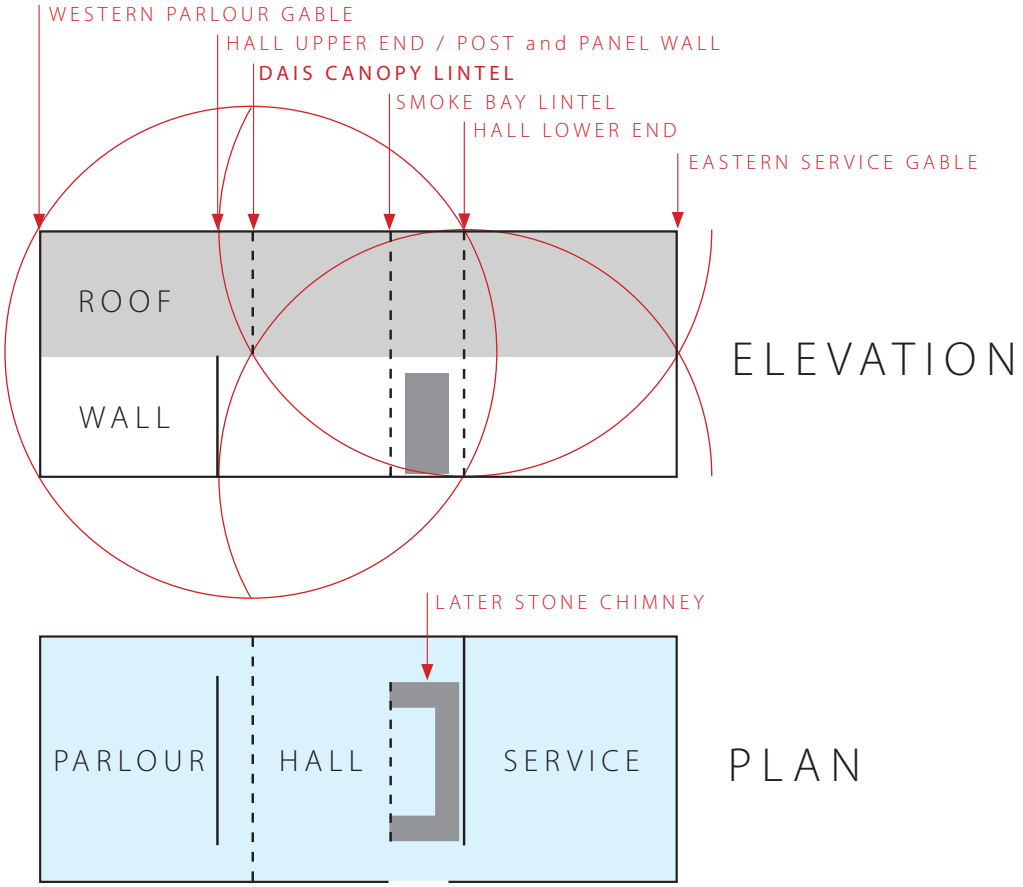


4 The daisy wheel, left, and Gwernfyda's geometrical symbols



5 Designing the floor using Gwernfyda's western gable symbol

The two symbols are clearly derived from the daisy wheel shown as a reference in grey line in figure 4. Considering the gable symbol first, in figure 5A, the two selected arcs enable the construction of a perfect square by drawing horizontal and vertical parallels through the ends of the arcs and as a tangent to them. The square is shown in blue tone. In figure 5B, two additional verticals can be drawn between the arcs, one as a diameter passing through the wheel's centre and one through the intersection of two dashed red lines linking the ends of the arcs, to mark the dais canopy and smoke bay, both within the overall square of the hall floor which is also extended left to the parlour gable. In figure 5C the two arcs are extended right to intersect at the service end gable.

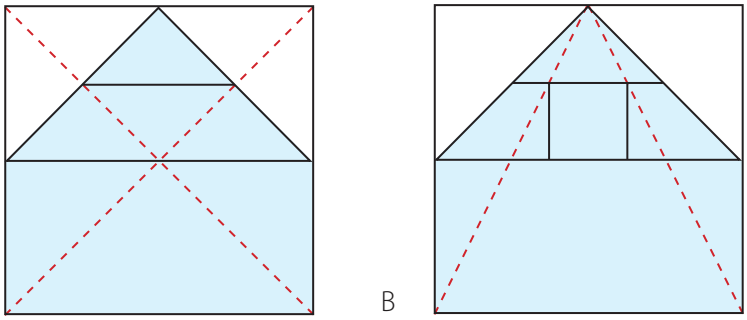


6 Elevation and plan from Gwernfyda's western gable symbol

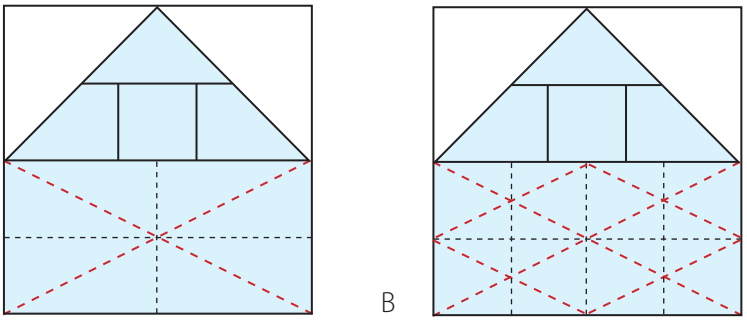
Figure 6 shows how the geometry can be read both as a long section, with the wall plate's top level at the circle's horizontal center line, and as a plan. The master carpenter was clearly aware of the relationship between the compass-drawn symbol and the square geometry that it generates. However, the compass characteristics of the design are dominant, and this is confirmed by the fact that the dais canopy, a feature of status in houses of the 16th century, is placed exactly at the heart of the circle on its vertical diameter.

The hall is 20 feet square and 20 feet high from floor to ridge. The gable's geometry is therefore also governed by the square. In the first stage of the design, the square's full diagonals cut the square in half to generate alignments for the lower wall, roof pitch and collar, figure 7A. Two further half-square diagonals cut the collar at the heads of the queen posts, figure 7B. Having resolved the primary elements of the roof truss, the design proceeds in the lower wall section. Diagonals are introduced to find the midpoint used to divide the frame into four quarters, figure 8A. The quarters are then individually subdivided, by the use of further diagonals, into halves, figure 8B. *This division of the lower wall frame is a temporary geometrical stage en route to further subdivision.*

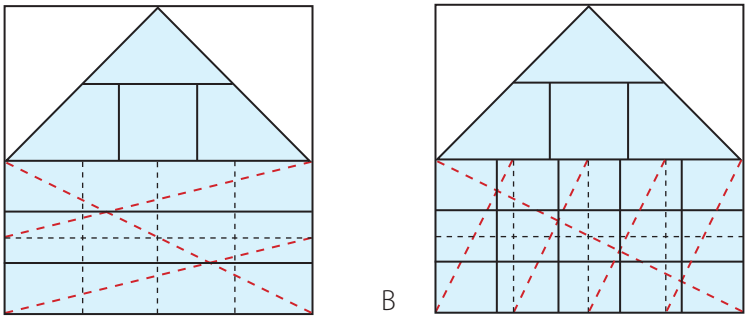
The traditional configuration of lower gable wall framing in Gwernfyda's area is three panels high by five long, a subdivision also obtained by further diagonals. First, the two horizontal bands established in figure 8 are crossed individually by diagonals, then jointly by a single diagonal in the reverse direction, figure 9A. Where these diagonals intersect, they divide the lower wall into three horizontal sectors. Similarly, the four vertical bands of figure 9A have their individual vertical diagonals intersected by a full horizontal diagonal in the reverse direction to divide the lower wall into five vertical sectors, figure 9B.



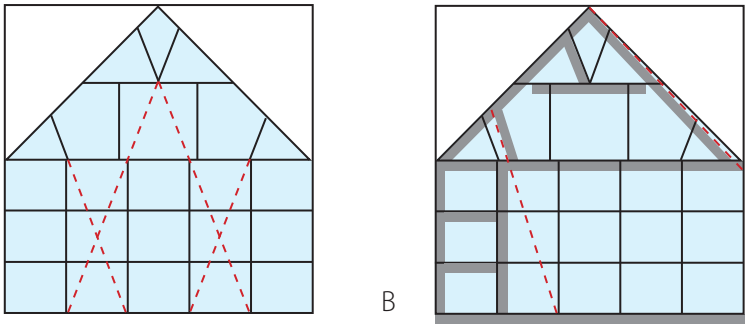
7 The square used to define A, the tie beam and collar and B, the Queen posts



8 Diagonal division to generate A, a 2 x 2 panel wall and B, a 2 x 4 panel



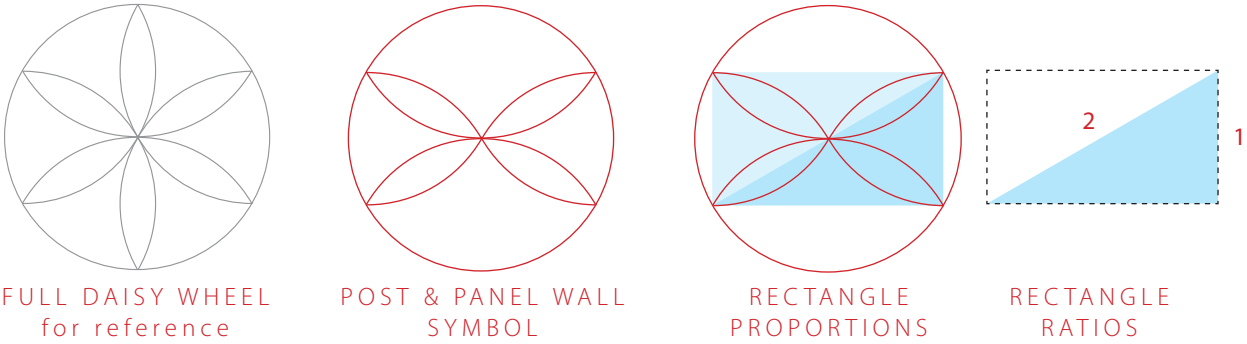
9 Diagonal division to generate A, 3 vertical panels and B, 5 horizontal panels

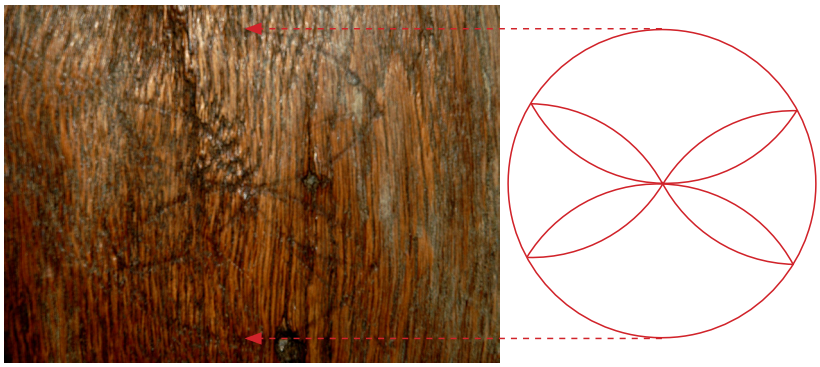


10 Diagonal divisions to generate A, gable braces and B, 5 horizontal panels

The final stage in the gable geometry is the location of braces in the roof truss, again determined by diagonals drawn across the grid of the lower wall's 3x5 panelling. The diagonals define the braces rising from both tie beam and collar to the principal rafters and it is interesting to observe that they emanate from the lower wall geometry, figure 10A, and unite the truss with it. At Gwernfyda, translating the pure geometry into practical framing was carried out in a pragmatic way with timbers placed to avoid overlapped joints.

11 ABOVE Western gable principals, braces, tie beam, collar, ridge tie and ridge beam
12 BELOW Post and panel wall proportions generated from daisy wheel symbol





13 Gwernfyda's four-petalled post and panel wall daisy wheel symbol

The second of Gwernfyda's symbols is scribed finely into the lower face of the hall's post-and-panel wall, which comprises a horizontal sill and wall plate connected by eight vertical posts and, between them, seven panels. There is a door at either side with the hinge pins still evident in the building's long outer walls. The doors are missing but would have opened into the parlour and rested against the outer walls. The symbol is again daisy wheel based, as in Figure 12, and depicts four of the usual six vesica petals. If the four vesica tips at the circle's circumference are connected, a rectangle is produced, identical to the rectangle so prominent in Ty-mawr's design. The rectangle has the ratio 1:2 between its short side and diagonal, and these are the exact proportions of Gwernfyda's post-and-panel wall. The divider-scribed wheel is shown at the centre of figure 13 with a red replica wheel alongside on the right.

14 Post and panel wall daisy wheel proportions and dimensions

Figure 14 shows the post and panel wall's 1:2 proportions between the vertical short side and diagonal. The dimensions echo the proportions with the vertical short side at 88 inches (7 feet 4 inches) and the diagonal at 176 inches (14 feet 8 inches). The imperial dimensions are given because these were the dimensions used when the frame was cut and raised.

An interesting aspect of the dimensions is that the unit side of the wall (the short side) is 88 inches in height. In the medieval period the primary dimension was the Rod (16½ feet), itself half the double Rod of 33 feet, the first whole number in the diminishing series of fractions ~ 33 16½ 8¼ 4⅛ 2 1/16 1 1/32 . Each fraction is half the next greater and twice the next smaller so that it is easy mentally to calculate doubling or halving. Doubling and halving also fits comfortably with the radius (half the diameter) and diameter (twice the radius) of compass geometry.

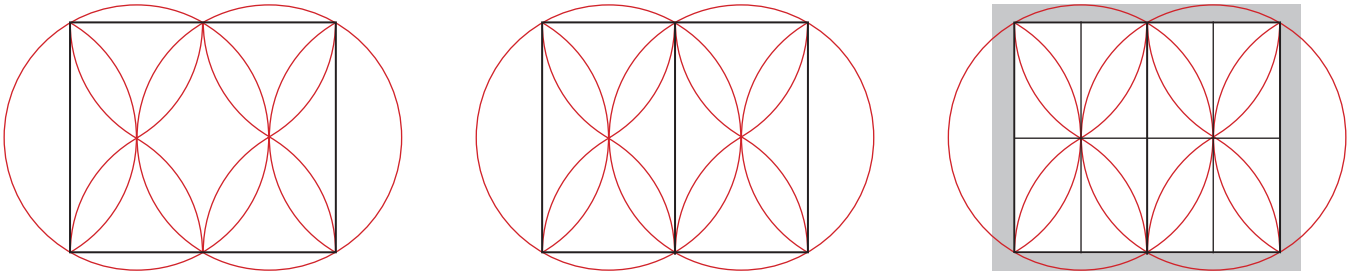
The Rod, divided into three gives dimensions of ~ 5½, 11 and 16½ feet. It can be seen that two thirds of a Rod, 11 feet, is one third of the Double Rod of 33 feet. Also, four Rods are 66 feet and six Rods are 99 feet. These 11-base numbers fall between the Imperial 12-base numeration and modern 10-base decimal numeration but are mentally much simpler, can be counted on the fingers and retained as a mnemonic ~

11 22 33 44 55 66 77 88 99

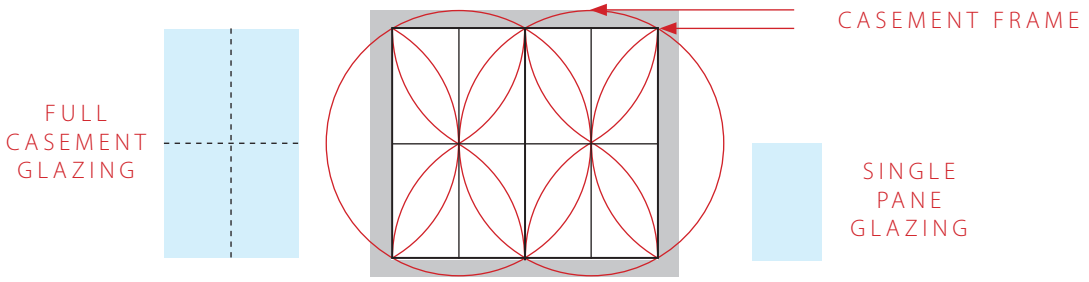
These dimensions appear in many medieval buildings, Salisbury Cathedral's facade is 99 feet wide, Ely Cathedral's nave is 88 feet wide externally and 77 feet internally (with the difference between the two walls at 11 feet so that each wall is 5½ feet thich, the same as the depth of the foundations). Burgage plots in Ludlow are 33 feet wide. Gwernfyda's 88 inch high post and panel wall fits into this 11-base system perfectly and, as the short side of the rectangle, is also the radius of the circle. A design circle drawn with an 8 inch radius is at 1:11 scale to the full size wall so that any divider dimension taken from the drawing can simply be stepped out 11 times along a chalk line to determine full scale.

The previous owners of Gwernfyda, which they bought as a listed building, had installed illegal and unsympathetic windows throughout the house, and these, the conservation planning officer agreed, had to go. Because there were no historic precedents to follow, the need arose to design modern windows and it seemed appropriate to apply the proportional influence of the symbol so that

the new windows could relate to the existing spaces that they would occupy. Figure 15 shows how the horizontal post-and-panel wall symbol was spun through 90 degrees into a vertical position and duplicated to form a two-circle sequence with each circle generating a casement rectangle. The distance between the casement rectangle's short side and the circle's circumference is occupied by the window's outer frame. Perpendiculars in each circle determine the alignment of glazing bars that divide each casement into four panes. Each pane is in identical proportion to the full casement, figure 16. A window in situ, figure 17.



15 ABOVE Double daisy wheel window casement geometry
16 BELOW Double daisy wheel window casement proportions

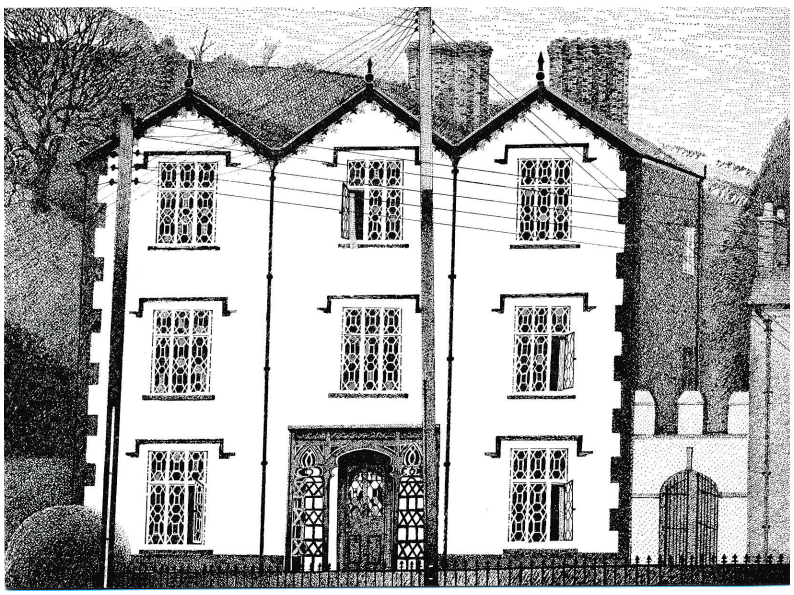


17 Modern daisy wheel window adjacent to the dais canopy and post and panel wall

18 Owl boss on transverse ceiling beam
19 Geometrical painting on a smoke bay stud
20 Quatrefoils on fireplace lintel
21 Phoenix on fireplace lintel
22 Running stag with antlers on fireplace lintel
23 Running hound with collar on fireplace lintel
24 Amphisbaena (double-headed serpent) on fireplace lintel
25 Crucifixion on fireplace lintel

THE HALL (Plas Uchaf)
Llanfyllin, Montgomeryshire

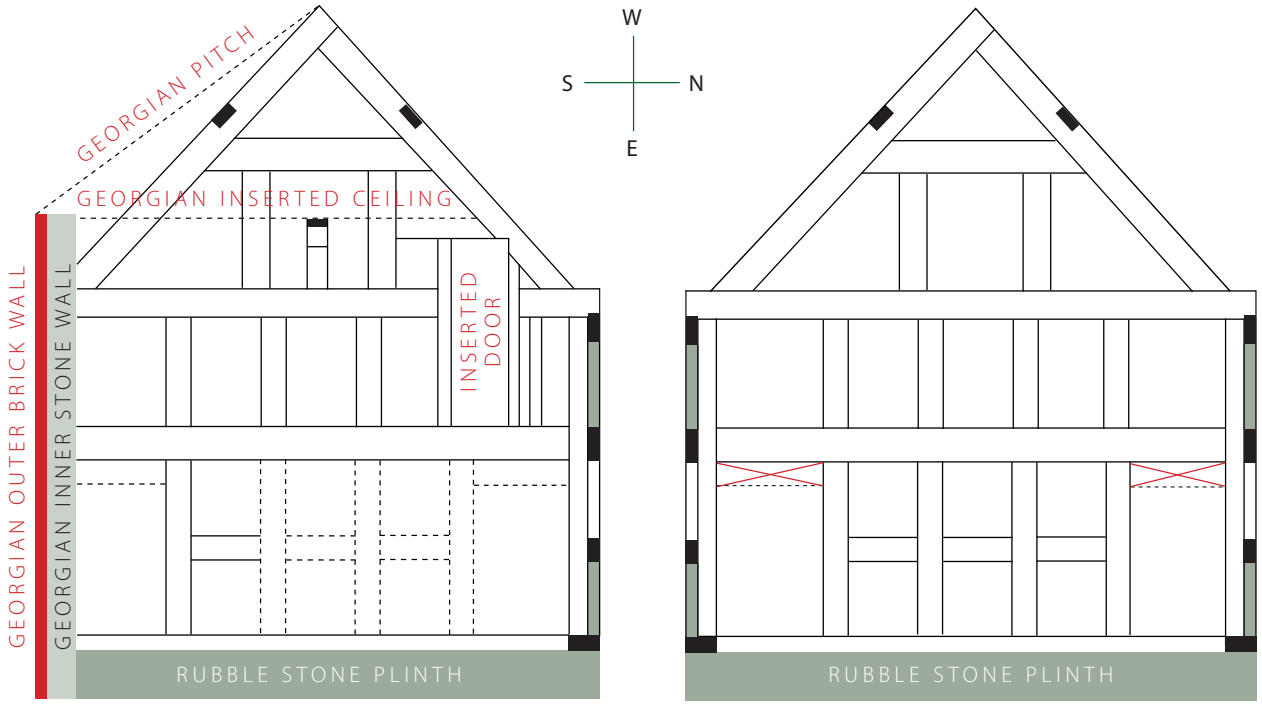
The Hall was built on rising ground on the edge of the small town of Llanfyllin in the old county of Montgomeryshire about 10 miles north of Ty-mawr and a similar distance west of the English
border. According to Tony Parkinson's estimate (he was a member of the Royal Commission on Ancient and Historic Monuments in Wales at the time) the house was originally built somewhere between 1500 and 1550 as a timber framed two-bay hall house sited parallel to the southern slope of the hillside for protection from winter north-westerlies. The house was built on a northeast south-west axis that allowed morning sunlight from the east and afternoon sunlight from the west into the full length of the house. A cross-wing was added at the southern end of the house in 1599, a date that survives in a carved inscription above the front door inside the current porch. In 1599 the house was approaching its social zenith, boasting a two-story porch, stair tower and a four seat outside latrine lined with stone and slate (high-quality sanitation, according to Tony Parkinson of The Royal Commission) and flushed out by a small rivulet on its way from Coed Llan (the holy wood) to Afon Cain (the beautiful river). Its terraced gardens, laid out with a line of eight yew trees and box-hedged parterres covering half an acre, stretched down to the town's high street. For a single night in September 1645, King Charles I stayed at The Hall en route for Chester. In 1832, everything changed. The cross-wing was built over to give a third floor and the house was revamped in the *renaissance* fashion of the time as a three-bay, three-storey *box* with shallow roof and three gables. The new façade was endowed with the latest in pattern-book windows, a front door with related glazing and an oak trellis porch, figure 1.



1 The Hall, Llanfyllin. Drawing by Laurie Smith

The form of much of the original house has been lost, but the service end, the kitchen end to this day, preserves significant elements of a two-bay hall

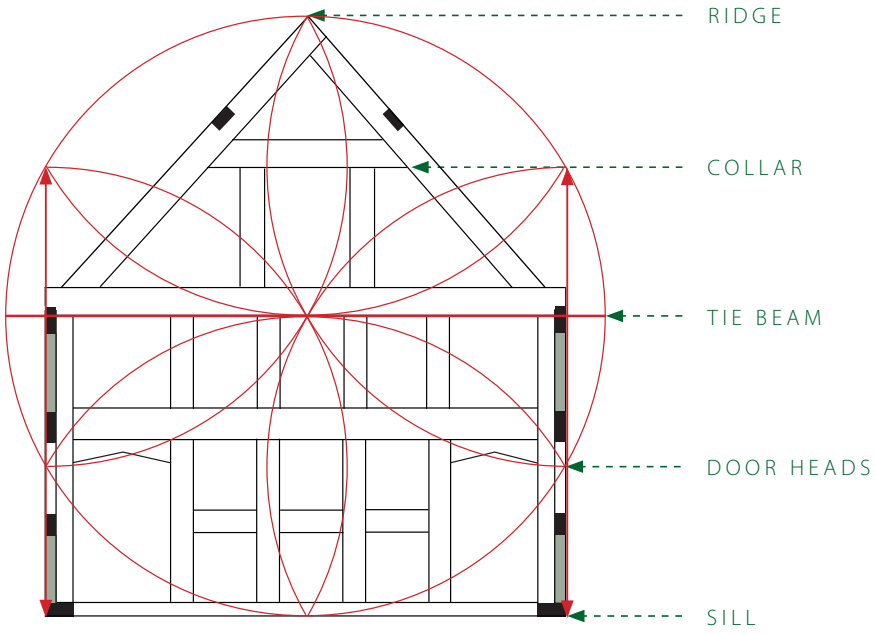
and service room that still retain their medieval character with framing visible internally. In the front of the house, which has Georgian (six-panel) doors in all rooms, the framing is either lathed and plastered or rebuilt in brick and stone. In the modern period, the house was in divided occupation, the formal gardens became allotments and the line of yew trees was felled and sold for convertion into veneer. The house is listed Grade II. Despite the Hall's well-documented history from 1600 to date, the original owner of the house remains unknown. The service room of the original building survives almost intact. The wall dividing it from the hall has carpenter's marks, visible mortises, peg holes, sills, wall plate levels and an adjacent wall of framing that make an accurate reconstruction of its missing timbers possible. Figure 2A records the existing wall and figure 2B shows the reconstruction. The adjacent south wall (in the cross-section on the left in 2A) was rebuilt in 1832 in stone faced with local handmade red brick and the roof raised on the same side, while the north wall opposite (in the cross-section on the right in 2B) survives. It is a fact of frame survival in wet Wales that, while the winter sun is low in the sky, north walls are shadowed and frozen throughout the winter months but thaw again in early spring. Rainwater in the texture of south walls freezes every night and thaws again each day so that the amalgamated over winter erosion is severe. North walls survive, south walls perish and are replaced.



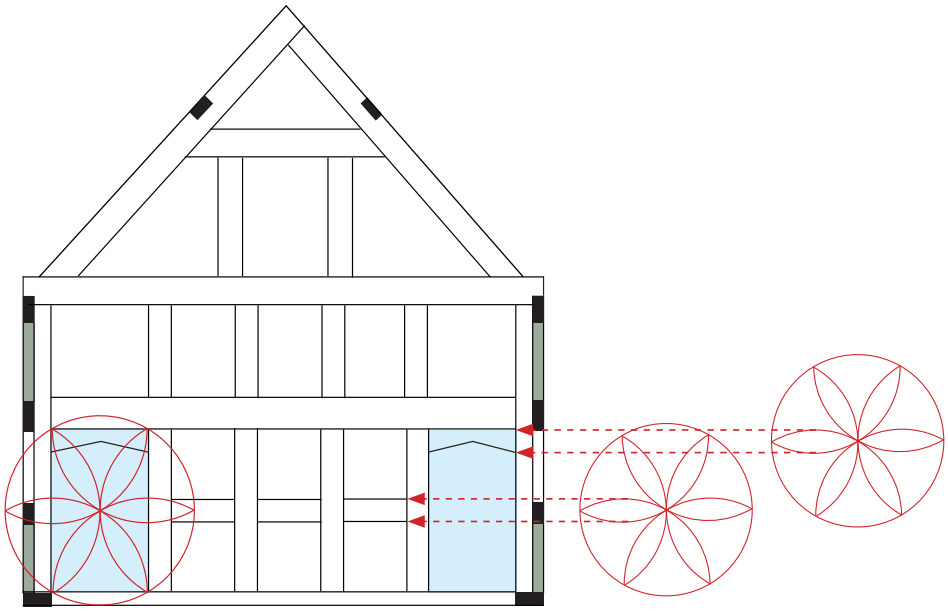
2 ABOVE LEFT Measured drawing of the hall lower end truss
2 ABOVE RIGHT The reconstructed truss

The hall lower end truss is determined by daisy wheel geometry, figure 3. The vertical vesicas define the frame's height from ground to ridge, while connection of the remaining four vesica tips generates the vertical planes of the outer walls and the horizontal base of the collar and the doorhead levels. The circle's horizontal diameter defines the base of the tie beam. It is clear that the daisy wheel's six radial petal tips are the cardinal geometrical locations driving the design of the truss, that the wheel would be easy to scribe on wood or plaster using dividers and that these locations could be connected using a straight edge.

3 The daisy wheel geometry of the reconstructed truss



3 The daisy wheel geometry of the reconstructed truss

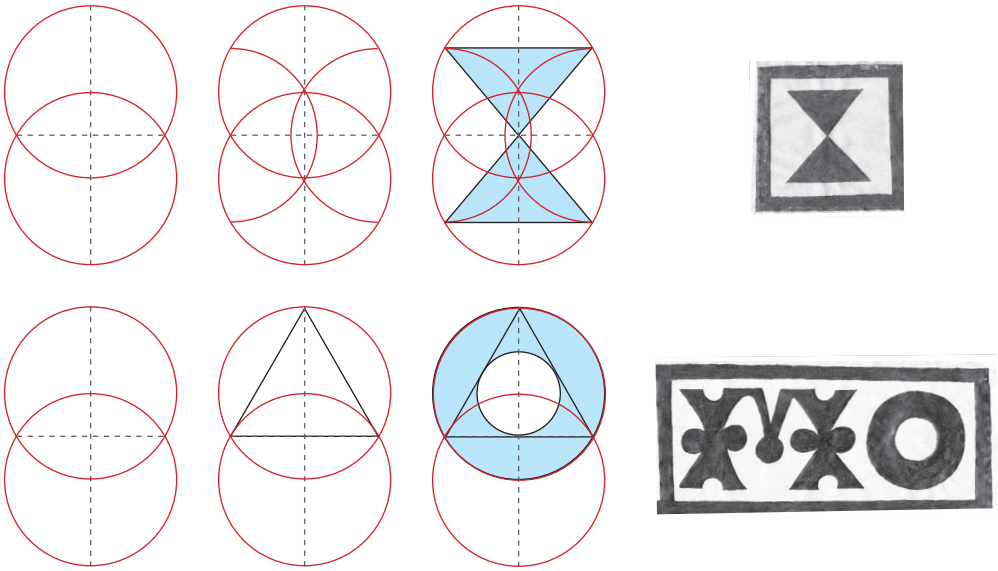


4 The daisy wheel symbol defines the door, door head proportions and tie depth

Figure 4 shows how the daisy wheel is also used at a smaller scale as a proportioning device to determine the combined rectangle of the doors and their doorheads. The horizontal vesicas also determine the doorhead depth and the depth of the ties in the lower wall framing between the door jambs.

In the 1832 remodelling of The Hall, a late 16th century carving encompassing the date 1599 and the initials C (or G) HMO, figure 5, was removed from its location within the house, and repositioned in the front door's trellis porch.

5 The carved date



6 ABOVE The geometrical design of **1**
BELOW The geometrical design of **O**

In local memory, the date carving was thought to be incorporated in panelling at the hall's upper end but was repositioned in the remodelling of the house as a lintel above the newly inserted front door inside its protective trellis porch. Standing in this porch 30 years ago and seeing the carving for the first time, the first number **1** of the date and the last letter **O** of the initials stood out from the remainder with a clearly geometrical prominence for which, initially, there seemed no reason. But I knew immediately that they held a message and made a full scale rubbing that would enable me to analyse the lettering geometrically. Analysing the **1** and **O** geometrically established that both resulted from related precision circle-based geometries, figure 6.

Drawing the geometrical 1, from left to right, commences with two circles drawn along a centerline so that each passes through the other's center to generate a vesica piscis, left. Arcs are drawn from either end of the central horizontal vesica until they intersect the circumferences of the circles, centre. The four points of intersection are connected by two lines in the form of an X to generate the two opposed triangles, right.

Drawing the geometrical O commences in an identical way to generate a vesica piscis, left. The two points of the vesica and the point of intersection between the center line and the upper circle's circumference are connected by three lines to form an equilateral triangle, centre. The O is formed between two circles, the larger passing through the triangle's vertices, the smaller as a tangent to the triangle's sides, right.

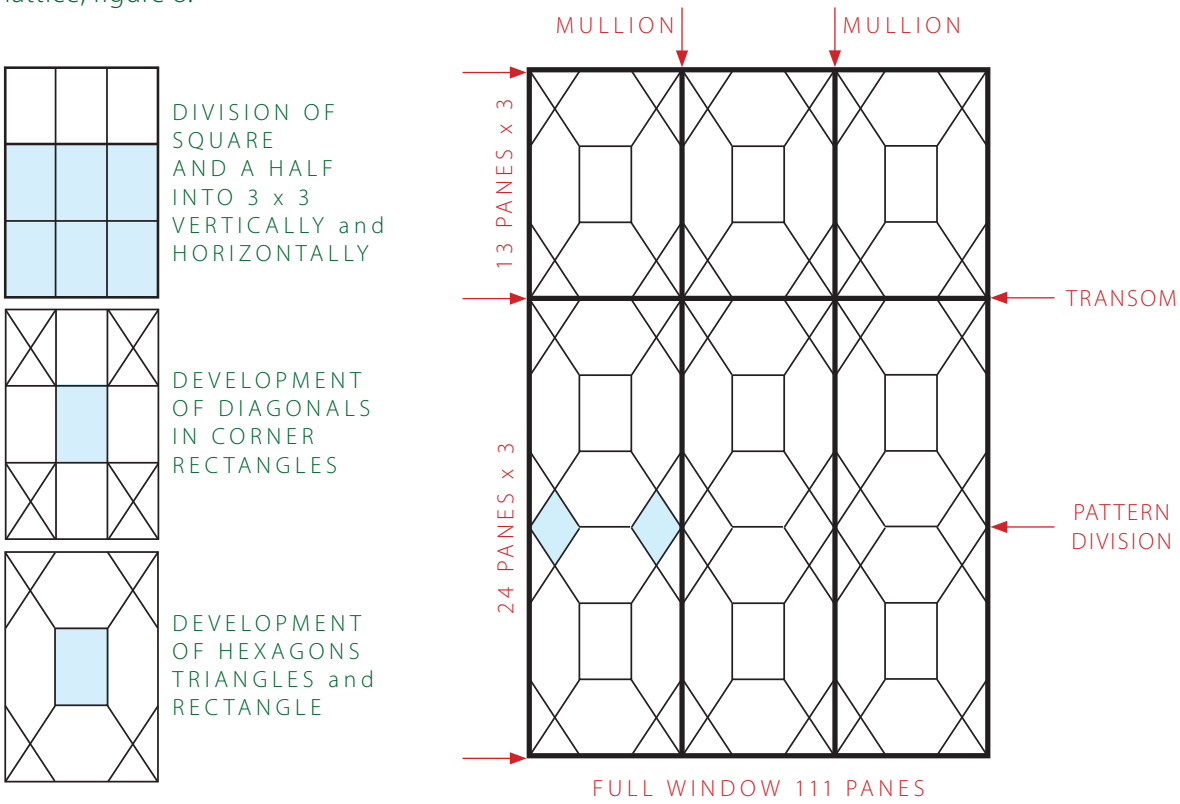
The X was the first clue to meaning. If X was posing as a 1, then what did XO mean? The Hall had been the home of recusant Catholics, forbidden by law to practice their religion in the 16th century. The XO was a sign to those with classical and biblical knowledge that the house was a safe house for Catholics, its meaning hidden in the Greek word *ICHTHYS* meaning a fish (the earliest Christian symbol, each letter of which is the first letter of the words Jesus Christ, Son of God, Saviour), figure 7 ~

Ι **Χ** **Ο** Υ Σ

7 The Greek spelling that underlies the geometrical design of **1** (X) and **O**
NOTE that X is on the left and O on the right, exactly as in the carving

When The Hall was remodeled in 1832, the side wall of its two-storey cross-wing was raised by a further floor and the whole three storeys became the new front of the house, punctuated by a central front door and eight pattern-book windows arranged in three bays across the facade. Windows of this nature were usually of cast iron, but The Hall's were blacksmith forged, the hot iron beaten into narrow strips, angled to the pattern's edict and fire welded. On the inside of the window lattice, half-cylindrical sections of copper were added to hold the glazing in place, the glass puttied on its outer face. Through the years of gradual decline the windows' interior grid had faded to a dull metallic bronze but it was clear that when first glazed the interior grid would have glowed as a bright grid of polished copper, framing the geometrical pattern of glass panes suspended within it.

The window design commences from a rectangle that is a square and a half in proportion, a ratio of 2 : 3 between its horizontal and vertical sides. The rectangle is divided into three both vertically and horizontally, so that the window has two vertical mullions and a transom across the top of the square. The configuration generates nine areas of glazing, three above the transom and six (in three pairs) below it. The subdivision of the full window is repeated in each of the nine small glazing areas. Diagonals are drawn in the corner rectangles of the nine small glazing areas, and some elements of the horizontal and vertical alignments are removed so that an individual area has 13 panes of glass: one central rectangle, two short hexagons at the head and foot of the rectangle, two long hexagons at either side of the rectangle and four pairs of triangles at the corners. The areas above the transom follow this pattern exactly but, because those below the transom are joined in pairs, the pattern is modified at the join where pairs of small triangles fuse to form diamonds (two are shown in blue tone). The double areas below the transom have 24 panes of glass. There are 37 panes in each vertical sector and 111 panes of glass in the full window lattice, figure 8.

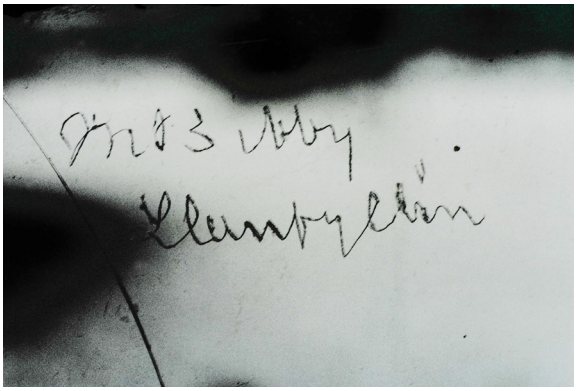


8 The geometrical development of the windows from a square and a half

The façade comprises eight of these 111 pane windows, making 888 panes of glass, and the front door's additional 64 bring the total to 952 panes. Each pane of glass is an individual geometrical pattern element, figure 9 above the transom, where the five basic shapes are shown as blue tone. In figure 9, below the transom where two sectors of the pattern link, the grid generates further diamond and triangular panes as well as hexagons and octagons based on the full width between the mullions and the window's external boundary.

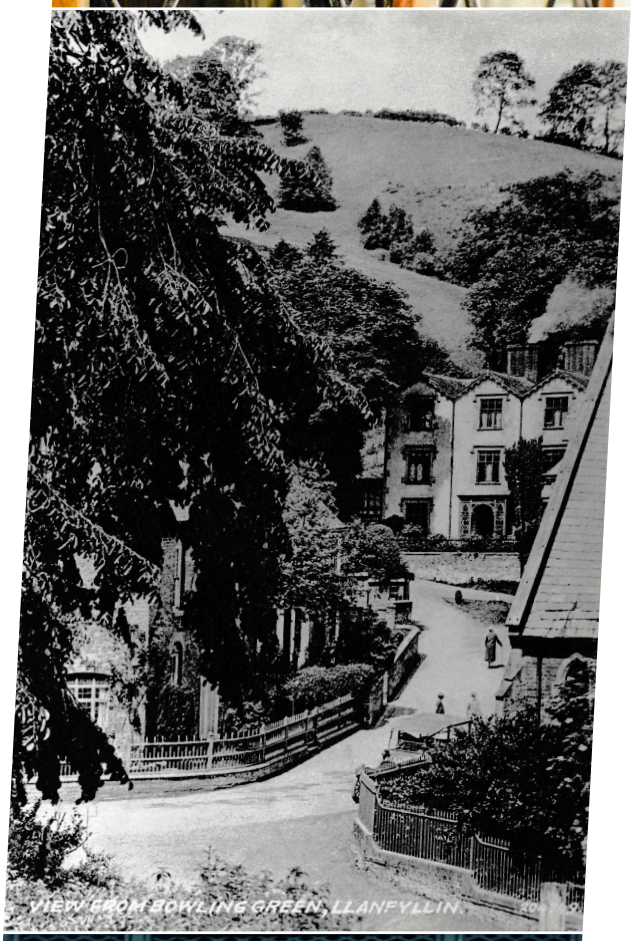
9 The geometrical pattern development of the windows from a square and a half

The redesign of The Hall's facade in 1832 is attributed to the town solicitor Maurice Bibby who purchased the house in that year and built a smaller house right alongside on the edge of the garden as an office. A window overlooking the garden bears his signature, M Bibby, Llanfyllin, scribed into the glass with his diamond ring, on the inside looking at the view outside, figure 10.



10 Maurice Bibby's signature window

11
12
13



11 The geometry of the doorhead windows
12 The Hall facade on a Victorian post card with Coed Llan in the background
13 The lattice-work porch and location of date carving above the front door

FOOTNOTE 1

The three examples discussed in this article demonstrate the presence and evolution of geometrical design between 1460 and 1832 in a small area of north-eastern Wales. The flow is clearly from early circle-based to later square geometries. Tŷ-mawr's and The Hall's first phase are pure circle geometries while Gwernfyda is a hybrid circle and square system and The Hall's 1832 façade purely square. The Hall's façade also records the fundamental shift away from geometry as the generative force behind structure toward geometry used solely as a source of pattern. Put another way, the trend marks the conceptual transition from compass and curved line design methods to measured ruler and straight line systems and the accompanying detrimental change from proportional to solely dimensional design.

It is noticeable that Tŷ-mawr, Gwernfyda and The Hall's first phase are all governed in their design by the use of related geometrical modules: carved into the frame at Tŷ-mawr, scribed into the frame at Gwernfyda and deduced from geometrical analysis at The Hall. The use of geometrical modules in the design of buildings has a direct European lineage, probably via the Norman invasion and conquest of the British Isles, from Vitruvius, the Roman architect of 100 BC and author of the Ten Books on Architecture, who wrote:

. . . . difficult questions involving symmetry are solved by means of ***geometrical theories and methods*** *. . . . Symmetry is the proper agreement between members of the work itself . . . . . between the different parts and the whole general scheme, in accordance with a certain part selected as standard . . . . symmetry may be calculated from the thickness of a column . . . .* ***or from a module****.*

The bold italics are mine. The module was clearly alive in Wales, its form a simple evolution from the tangible thickness, or diameter, of a column to its circumference, the circle. The circle was mobile. It could be revolved to transform the direction of any internal geometry. It could be multiplied along a centre line to generate harmonically proportioned grids from which linear alignments and rectilinear areas could be established, and it could encompass subgeometries that enabled fine-tuning of the design. The daisy wheel is ubiquitous in historic buildings; in fact, its absence is more noteworthy than its presence. As demonstrated, analysis of its geometrical properties and their testing against the measured drawings of a building often reveal evidence of its function as a design module governing the building's major proportions and bay rhythm. Many variations of the daisy wheel's basic geometry also exist, and the idiosyncratic symbols found at Tŷ-mawr and Gwernfyda record the presence of individual and intellectually sophisticated geometrical design approaches in operation in eastern Wales between the 15th and 17th centuries. By 1832, when The Hall's windows were installed, medieval geometrical design systems had had their day, but geometry enjoyed a resurgence in the decorative window glazings that were offered nationally as choices in pattern books.

Editor's note from **TIMBER FRAMING**, Volume 70, 2003

Laurie Smith, an accomplished artist and scholar living in Wales, has widely studied the geometry underlying historic building design. This article was developed from his talk ***Welsh Historic Geometrical Building Design*** at the UK Carpenters' Fellowship conference ***Frame 2003*** held at

Amgueddfa Werin Cymru, Sain Ffagan, Caerdydd, Cymru
The Museum of Welsh Life at Saint Fagans, Cardiff, Wales

FOOTNOTE 2

Welsh pronunciation and meaning ~

TŶ MAWR translates as the Great House, the English in reverse order to the Welsh where TŶ means house and MAWR means great. The word TŶ is interesting because the accent above the Y is known in Welsh as To Bach or little roof, with To meaning roof and Bach meaning little. So the Welsh word for house embodies a little roof. TŶ is pronounced as tea and MAWR rhymes with hour, the final R being rolled off the tongue.

GWERNFYDA is a composite of two words, GWERN meaning marsh or an alder tree (alders grow in marshy ground) and FYDA meaning a wild bee swarm. FYDA is a contraction of the word BYDAF but, in the specific grammatical context of the house name, the initial B mutates to F and, in the local Montgomeryshire dialect, the final F is not pronounced. The pronunciation is complicated by the fact that a Welsh F is pronounced the same as an English V. So GWERNFYDA is pronounced Gwernvudda, with Gwern more like Gwairn with the r rolled off the tongue.

THE HALL, Llanfyllin. The house has been known by its English name since the 17th century, but it is also known to Welsh speakers in the bilingual town as PLAS UCHAF, The Upper Hall. The Welsh word PLAS describes a gentleman's residence and UCHAF means higher (either in status or in altitude, for example on a hill). PLAS is pronounced as the first syllable of plastic. UCHAF is more difficult to the English tongue, the U is pronounced as English I (as in the word ink), the CH is pronounced as a hard C or K, the A as English a and the F, in the local Montgomeryshire dialect, is not pronounced. So Welsh UCHAF is pronounced ICA in Welsh and English.

My wife, Hilary, and I lived in Wales for 25 years. The Hall, Llanfyllin was our first home for 8 years and Gwernfyda, Llanllugan our second for 17 years. When we bought them, both houses were in a neglected state, had been on the market for a long time and, despite being of significant architectural and historical interest, attracted no local buyers. However, in both houses we were warmly welcomed by neighbours who had feared further dereliction or demolition and were pleased to see these houses being brought back to life. In many ways we were out of our depth for there were steep philosophical and practical learning curves in the field of historic building repair and vertical ascents in the fields of Welsh culture, history and language. So, plunging in at the deep end, we learned to swim and were rewarded beyond our dreams. Living in the houses was to live simultaneously in the past and the present, to work at a slower, manual rhythm using hand tools, to discover and apply the geometrical aesthetic of the past. Above all, these houses were a pleasure to live in, their atmospheres rooted deep in Welsh landscape, history and culture. As with all historic houses, we were merely guardians for the duration of our time as residents but we were proud to have left both houses in significantly better condition than we had found them in.

www.historicbuildinggeometry.uk

HISTORIC
BUILDING
GEOMETRY
Laurie
SMITH