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Oxford Dendrochronology Laboratory

THE TREE-RING DATING OF

**Llanfair Isaf, Harlech**  
**Merioneth**

Report2010/100



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A report commissioned by The North West Wales Dendrochronology Project in partnership with The Royal Commission on the Ancient and Historical Monuments in Wales (RCAHMW).

Oxford Dendrochronology Laboratory  
Report 2010/100  
The Tree-Ring Dating of Llanfair-isaf,  
Harlech, Gwynedd, Wales  
M J Worthington and D W H Miles

Summary:

HARLECH, Llanfair-isaf (SH 5755 2885)

(a) Primary phase                    Felling dates: **1530-60, 1539-69, 1541-71, and 1540-67**

(a) Collar (0/2); Rafter (2/2) 1519, 1526 (HIS), Purlin 1517, 1530 (HIS).

Site Masters (a) 1416-1530 ISAF (t - 11.85 CEFNCARI; 10.19 WALES97; 9.87 GWYDWN).

LLANFAIR-ISAF (Llanfair, Merioneth)

Royal Commission's NPRN: 28521

Llanfair-Isaf is a classic instance of the 'unit system', where several apparently independent domestic units are found in close association, sometimes built corner-to-corner, but are not intercommunicating. At Llanfair-ISAF there are three dwellings, with House I flanked on either side by Houses 2 and 3.

(1) House 1, the central house, is a storeyed house of Snowdonian type with a full cross-passage between the hall/kitchen with a large end fireplace and twin outer rooms. The principal first-floor chamber has a corbelled-out chimney. Several architectural details suggest a sixteenth-century date: the lack of a fireplace stair, the corbelled out fireplace, and a full cross-passage with doorways with voussoir and draw- bars

(2) House 2 (the Cottage or Bwthyn) is set corner-to-corer with House I and has clearly been built against it.

Nevertheless, the Cottage has an archaic plan and the hall/kitchen was originally open to the roof. The Cottage has a two-unit plan with hall/'kitchen heated by a large end fireplace and an outer bay that may originally have been floored over. This house of crogloft (half-loft) type was probably a dower house or widow's house, a well-defined house-type in Snowdonia.

(3) House 3 has been added to the other side of House I. It is a Georgian house of central stair passage type with end chimneys. This became the principal house at Llanfair-isaf and House 1 (with which it communicates) became a kitchen wing.

The RCAHMW survey has been published in Peter Smith's Houses of the Welsh Countryside (1975 & 1988), fig. 87.

Date sampled:                    30 September 2009  
Commissioner:                 Adnabod Ardudwy HLF Project  
Historical Research:         Richard Suggett  
Summary published:         Miles, D H, Worthington, M J, and Bridge, M C, 2011  
    dates, Vernacular Architecture 42, (forthcoming)

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August 2010

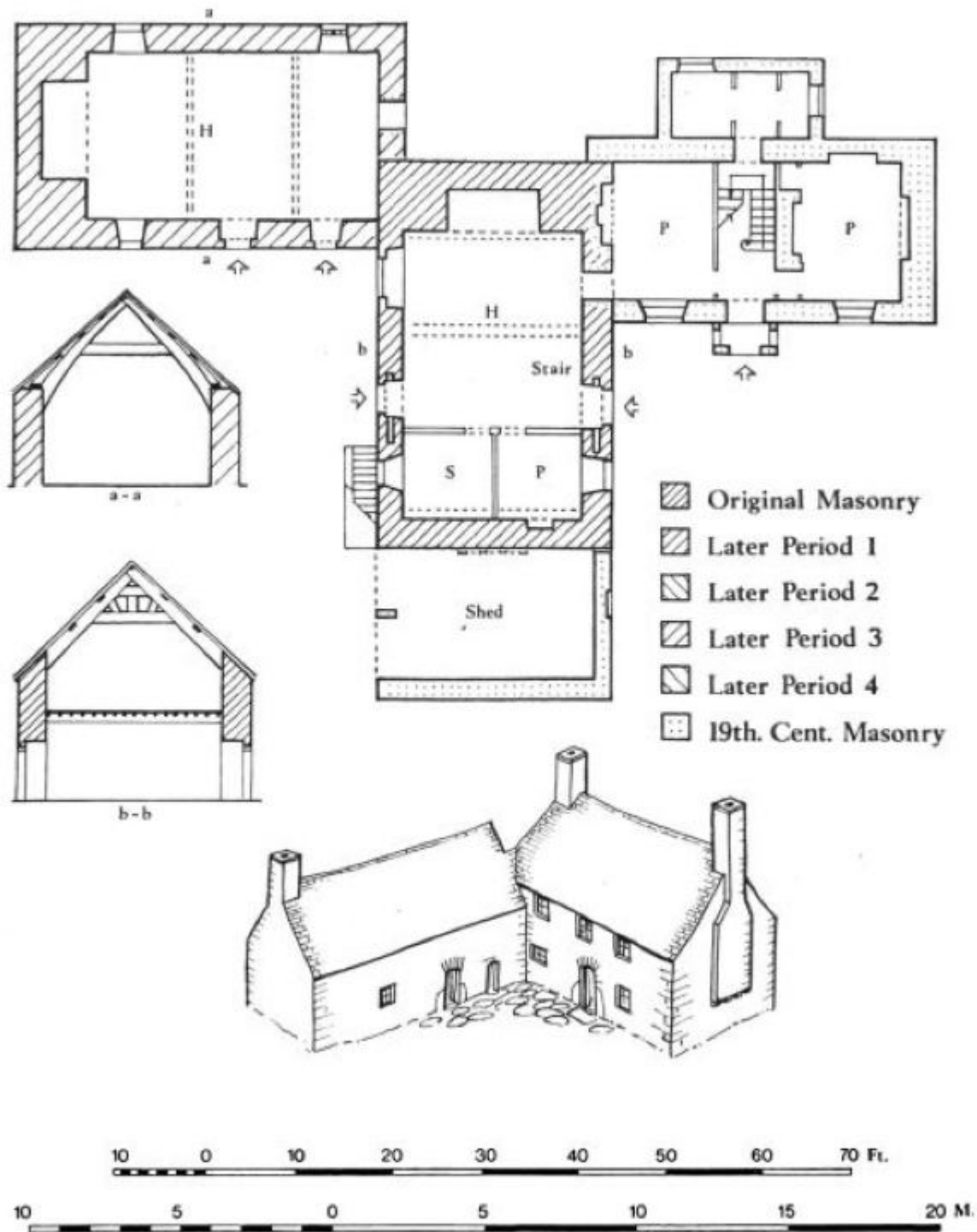


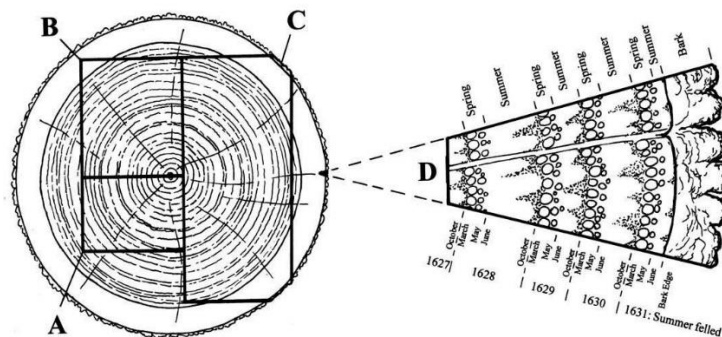
Fig. 87 This interpretation receives support from another development of the 'unit-system' where the two houses (this time built at right-angles) are not even inter-communicating, as in the first and second house at Llanfair-isaf (Llanfair, Mer.). Observe that when Llanfair-isaf was enlarged again, the addition formed a virtually independent unit. Note that it is the single-storeyed, raised-cruck house which follows the storeyed sub-medieval house. The perspective shows the pre-nineteenth century layout.

**Dendrochronology** has over the past 20 years become one of the leading and most accurate scientific dating methods. Whilst not always successful, when it does work, it is precise, often to the season of the year. Tree-ring dating is well known for its use in dating historic buildings and archaeological timbers to this degree of precision. However more ancillary objects such as doors, furniture, panel paintings, and wooden boards in medieval book-bindings can sometimes be successfully dated.

The science of dendrochronology is based on a combination of biology and statistics. Fundamental to understanding how dendrochronology works is the phenomenon of tree growth. Essentially, trees grow through the addition of both elongation and radial increments. The elongation takes place at the terminal portions of the shoots, branches, and roots, while the radial increment is added by the cambium, the zone of living cells between the wood and the bark. In general terms, a tree can be best simplified by describing it as a cone, with a new layer being added to the outside each year in temperate zones. making it wider and taller.

An annual ring is composed of the growth which takes place during the spring and summer until about November when the leaves are shed, and the tree becomes dormant for the winter period. For the European oak (*Quercus robur* and *Q. petraea*). as well as many other species. the annual ring is composed of two distinct parts - the spring growth or early wood, and the summer growth, or late wood. Early wood is composed of large vessels formed during the period of shoot growth which takes place between March and May, which is before the establishment of any significant leaf growth and is produced by using most of the energy and raw materials laid down the previous year. Then, there is an abrupt change at the time of leaf expansion around May or June when hormonal activity dictates a change in the quality of the xylem and the summer. or late wood is formed. Here the wood becomes increasingly fibrous and contains much smaller vessels. Trees with this type of growth pattern are known as ring-porous and are distinguished by the contrast between the open, light—coloured early Wood vessels and the dense, dark encoloured late wood.

Dendrochronology utilises the variation in the width of the annual rings as influenced by climatic conditions common to a large area, as opposed to other more local factors such as woodland competition and insect attack. It is these climate-induced variations in ring widths that allow calendar dates to be ascribed to an undated timber when compared to a firmly-dated sequence. If a tree section is complete to the bark edge. then when dated a precise date of felling can be determined. The felling date will be precise to the season of the year, depending on the degree of formation of the outermost ring. Therefore, a tree with bark which has the spring vessels formed but no summer growth can be said to be felled in the spring, although it is not possible to say in which particular month the tree was felled.



Section of tree with conversion methods showing three types of sapwood retention resulting in A terminus post quem. B a felling date range. and C a precise felling date. Enlarged area D shows the outermost rings of the sapwood with growing seasons (Miles 1997, 42)

Another important dimension to dendrochronological studies is the presence of sapwood. This is the band of growth rings immediately beneath the bark and comprises the living growth rings which transport the sap from the roots to the leaves. This sapwood band is distinguished from the heartwood by the prominent features of colour change and the blocking of the spring vessels with tyloses, the waste products of the tree's growth. The heartwood is generally darker in colour, and the spring vessels are blocked with tyloses. The heartwood is dead tissue, whereas the sapwood is living, although the only really living, growing, cells are in the cambium, immediately beneath the bark. In European oak (*Quercus robur* sp.), the difference in colour is generally matched by the change in the spring vessels. Generally the sapwood retains stored food and is therefore attractive to insect and fungal attack once the tree is felled and therefore is often removed during conversion. Sapwood in European oaks tends to be of a relatively constant width and/or number of rings. By determining what this range is with an empirically or statistically-derived estimate is a valuable aspect in the interpretation of tree-ring dates where the bark edge is not present (Miles 1997). The narrower this range of sapwood rings, the more precise the estimated felling date range will be.

### **Methodology: The Dating Process**

All timbers sampled were of oak (*Quercus* spp.) from what appeared to be primary first-use timbers. Or any timbers which might have been re-used from an early phase. Those timbers which looked most suitable for dendrochronological purposes with complete sapwood or reasonably long ring sequences were selected. In situ timbers were sampled through coring, using a 16mm hollow auger. Details and locations of the samples are detailed in the summary table.

The dry samples were sanded on a linisher, or bench-mounted belt sander, using 60 to 1200 grit abrasive paper, and were cleaned with compressed air to allow the ring boundaries to be clearly distinguished. They were then measured under a x10/x30 microscope using a travelling stage electronically displaying displacement to a precision of 0.01mm. Thus each ring or year is represented by its measurement which is arranged as a series of ring-width indices within a data set, with the earliest ring being placed at the beginning of the series, and the latest or outermost ring concluding the data set.

The principle behind tree-ring dating is a simple one: the seasonal variations in climate-induced growth as reflected in the varying width of a series of measured annual rings is compared with other, previously dated ring sequences to allow precise dates to be ascribed to each ring. When an undated sample or site sequence is compared against a dated sequence, known as a reference chronology, an indication of how good the match is must be determined. Although it is almost impossible to define a visual match,

computer comparisons can be accurately quantified. Whilst it may not be the best statistical indicator, Student's (a pseudonym for W S Gosset) t-value has been widely used amongst British dendrochronologists. The cross-correlation algorithms most commonly used and published are derived from Baillie and Pilcher's CROS programme (Baillie and Pilcher 1973), although a faster version (Munro 1984) giving slightly different t-values is sometimes used for indicative purposes.

Generally, t-values over 3.5 should be considered to be significant, although in reality it is common to find demonstrably spurious t-values of 4 and 5 because more than one matching position is indicated. For this reason, dendrochronologists prefer to see some t-value ranges of 5, 6, or higher, and for these to be well replicated from different, independent chronologies with local and regional chronologies well represented. Users of dates also need to assess their validity critically. They should not have great faith in a date supported by a handful of t-values of 3's with one or two 4's, nor should they be entirely satisfied with a single high match of 5 or 6. Examples of spurious t-



values in excess of 7 have been noted, so it is essential that matches with reference chronologies be well replicated. and that this is confirmed with visual matches between the two graphs. Matches with t-values of 10 or more between individual sequences usually signify having originated from the same parent tree.

In reality, the probability of a particular date being valid is itself a statistical measure depending on the t-values. Consideration must also be given to the length of the sequence being dated as well as those of the reference chronologies. A sample with 30 or 40 years growth is likely to match with high t values at varying positions, whereas a sample with 100 consecutive rings is much more likely to match significantly at only one unique position. Samples with ring counts as low as 50 may occasionally be dated, but only if the matches are very strong, clear and well replicated, with no other significant matching positions. This is essential for intra-site matching when dealing with such short sequences. Consideration should also be given to evaluating the reference chronology against which the samples have been matched: those with well-replicated components which are geographically near to the sampling site are given more weight than an individual site or sample from the opposite end of the country.

It is general practice to cross-match samples from within the same phase to each other first. Combining them into a site master, before comparing with the reference chronologies. This has the advantage of averaging out the 'noise' of individual trees and is much more likely to obtain higher t-values and stronger visual matches. After measurement, the ring-width series for each sample is plotted as a graph of width against year on log-linear graph paper. The graphs of each of the samples in the phase under study are then compared visually at the positions indicated by the computer matching and, if found satisfactory and consistent, are averaged to form a mean curve for the site or phase. This mean curve and any unmatched individual sequences are compared against dated reference chronologies to obtain an absolute calendar date for each sequence. Sometimes, especially in urban situations, timbers may have come from different sources and fail to match each other, thus making the compilation of a site master difficult. In this situation samples must then be compared individually with the reference chronologies. Therefore, when cross-matching samples with each other, or against reference chronologies, a combination of both visual matching and a process of qualified statistical comparison by computer is used. The ring-width series were compared on an IBM compatible computer for statistical cross-matching using a variant of the Belfast CROS program (Baillie and Pilcher 1973). A version of this and other programmes were written in BASIC by D I-laddon-Reece, and re-written in Microsoft Visual Basic by M R Allwright and P A Parker.

### **Ascribing and Interpreting Felling Dates**

Once a tree-ring sequence has been firmly dated in time, a felling date, or date range, is ascribed where possible. For samples which have sapwood complete to the underside of, or including bark, this process is relatively straight forward. Depending on the completeness of the final ring, i.e. if it has only the early wood formed, or the latewood, a *precise felling date and season* can be given. If the sapwood is partially missing, or if only a heartwood/sapwood transition boundary survives, then an *estimated felling date range* can be given for each sample. The number of sapwood rings can be estimated by using a statistically derived sapwood estimate with a given confidence limit. A review of the geographical distribution of dated sapwood data from historic building timbers has shown that a 95% range of 11-41 rings is most appropriate for Wales and the border counties (Miles 1997), which will be used here. If no sapwood or heartwood/sapwood boundary survives, then the minimum number of sapwood rings from the appropriate sapwood estimate is added to the last measured ring to give a *terminus post quem (tpq) or felled after date*.

An alternative method of estimating felling date ranges has recently been developed (Miles 2005) which runs as a function under OxCal (Bronk Ramsey 1995; Miles and Bronk Ramsey *in prep*).

Instead of using a simple empirical estimate for a particular geographical location, one model was found to be suitable for the whole of England and Wales. With the methodology set out by Millard (2002), Bayesian statistical models are used to produce individual sapwood estimates for samples using the variables of number of heartwood rings present, the mean ring width of those heartwood rings, the heartwood/sapwood boundary date, and the number of any surviving sapwood rings or a count of those lost in sampling. Using the suite of calculation and graphical plotting functions in OxCalinput and OxCalPlot (Bronk Ramsey in *prep*), the area of highest probability density for each sample can be graphically displayed to any of three confidence levels. The addition of surviving sapwood to the equation narrows the felling date range for each sample, although the outer end of the range shifts slightly later, more noticeably on those samples with higher sapwood counts. An empirically-derived stock-piling factor added to the ranges produced also helps to make the estimated felling date ranges more representative for the actual latest common felling date, from which a construction date can then be extrapolated.

This new method of predicting sapwood ranges has resulted in over 94% of the samples tested producing felling date ranges narrower than the 36-year empirical estimate currently used. About a quarter of the samples tested showed an improvement with a range of 24 years or less. Conversely, some 4.5% of the samples tested produced a range larger than the empirical range, but again these ranges are more representative of the actual sapwood found.

However, it has been found that some unusual samples do not fit the model well. These include samples which have exceptional or sudden variation in mean ring width, such as might be found in pollarded or managed timber. Sometimes a tree will exhibit a sudden drop in mean ring width toward the end of its life, resulting in more sapwood rings being present than might be suggested in the faster-grown heartwood. Additionally, samples which have come from small timbers converted from larger, slow-grown trees would have a much larger number of heartwood rings than were actually present in the sample. Some examples of heartwood ring counts of 25 years or less with a narrow mean ring width are good indicators of this situation, as were observations made during sampling. Samples with these characteristics should be excluded from such analysis.

A particularly useful feature of OxCalPlot is the ability of producing combined felling date ranges for a group of samples comprising a single phase of building. Here, two samples combined can reduce the individual felling date ranges from about 30 to about 20 years. By including more samples within the combined phase, this 20-year range can be reduced to half or even less, depending on the number of samples in the phase. Thus felling date ranges for combined building phases have the potential to being reduced by as much as a two-thirds or even three-quarters of the individual empirically-derived felling date ranges.

Some caution must be used in interpreting solitary precise felling dates. Many instances have been noted where timbers used in the same structural phase have been felled one, two, or more years apart. Whenever possible, a group of precise felling dates should be used as a more reliable indication of the construction period. It must be emphasised that dendrochronology can only date when a tree has been felled, not when the timber was used to construct the structure under study. However, it is common practice to build timber-framed structures with green or unseasoned timber and that construction usually took place within twelve months of felling (Miles 2005)‘



## Details of Dendrochronological Analysis

The results of the dendrochronological analysis for the building under study are presented in a number of detailed tables, The most useful of these is the summary Table 1. This gives most of the and its felling date or date range, if successfully tree-ring dated. This last column is of particular interest to the end user, as it gives the actual year and season when the tree was felled, if bark is present. or an estimated felling date range if the sapwood is incomplete. Occasionally it will be noted that the felling date ranges may coincide with the precise felling date ranges. This is nothing to be overly concerned about so long as these are not too far apart. It must be remembered that the estimated felling date ranges are calculated at a 95% confidence level, which means that statistically one sample in 20 will have felling dates which actually fall outside the predicted range.

It will also be noticed that often the precise felling dates will vary within several years of each other. Unless there is supporting archaeological evidence suggesting different phases. all this would indicate is either stockpiling of timber, or of trees which have been felled or died at varying times but not cut up until the commencement of the particular building operations in question. When presented with varying precise felling dates, one should always take the latest date for the structure under study, and it is likely that construction will have been completed for ordinary vernacular buildings within twelve or eighteen months from this latest felling date (Miles 1997),

**Table 2** gives an indication of the statistical reliability of the match between one sequence and another. This shows the I-value over the number of years overlap for each combination of samples in a matrix table. It should be born in mind that t-values with less than 80 rings overlap may not truly reflect the same degree of match and that spurious matches may produce similar values. First, multiple radii have been cross-matched with each other and combined to form same-timber means. These are then compared with other samples from the site and any which are found to have originated from the same parent tree are again similarly combined. Finally, all samples, including all same timber and same tree means are combined to form one or more site masters. Again, the cross-matching is shown as a matrix table of t-values over the number of years overlaps. Reference should always be made to **Table 1** to clearly identify which components have been combined.

**Table 3** shows the degree of cross-matching between the site master(s) with a selection of reference chronologies. This shows the county or region from which the reference chronology originated, the common chronology name together with who compiled the chronology with publication reference and the years covered by the reference chronology. The years overlap of the reference chronology and the site master being compared are also shown together with the resulting t-value. It should be appreciated that well replicated regional reference chronologies, which are shown in **bold**, will often produce better matches than with individual site masters or indeed individual sample sequences.

**Figures** include a bar diagram which shows the chronological relationship between two or more dated samples from a phase of building. The site sample record sheets are also appended, together with any plans showing sample locations, if available.

**Publication** of all dated sites takes place in Vernacular Architecture annually, and the entry. if available, is shown on the summary page of the report. This does not give as much technical data for the samples dated, but does give the r-value matches against the relevant chronologies, provide a short descriptive paragraph for each building or phase dated, and gives a useful short summary of samples dated. These summaries are also listed on the web-site maintained by the Laboratory, which can be accessed at [www.dendrochronology.com](http://www.dendrochronology.com). The Oxford Dendrochronology Laboratory retains

copyright of this report, but the commissioner of the report has the right to use the report for his/her own use so long as the authorship is quoted. Primary data and the resulting site master(s) used in the analysis is available from the Laboratory on request by the commissioner and bona fide researchers. The samples form part of the Laboratory archives.

### **Sampling**

This particular study of Llanfair-isaf was undertaken in an attempt to date all the construction phases of the structure in order to shed new light on the understanding of the development of the building. After assessing all the timbers within the three houses of the complex, it was found that only the timbers from the primary phase (House 1) were suitable. Six timbers in total from this roof structure were found to be suitable for dendrochronology and were sampled, Each sample was given the code **isaf** (for Llanfair-isaf) and numbered 1-6 (see table 1). The position of the samples was noted at the time of sampling (see figure 2).

Two ex-situ timbers from House I were also sampled, one from a cross-beam and one from a staircase.

### **Summary of Dating**

Six timbers were sampled from the primary range. Multiple samples were taken from one of the timbers, the upper purlin on the west side between trusses 3 and 4, in order to collect the maximum number of annual rings. The two cores from this timber were compared visually and combined to form the new individual sample sequence **isaf4**, which was used in the rest of the analysis. All the sequences were compared with each other. Four of the six timbers (**isaf3 - isaf6**) were found to cross-match, allowing them to be combined into the 115-year site master **ISAF**. This site master was found to date spanning the years 1416- 1530 (see table 3).

The two ex-situ samples did not match against the new site master or the dated master chronologies and therefore remain undated.

### **Interpretation**

The tree-ring analysis has resulted in the successful dating of four of the samples from the primary phase (House 1) of Llanfair-isaf. None of the timbers retained complete sapwood so only estimated fellingdate ranges could be found for each of them. The date ranges were calculated using the sapwood estimate of 11-41 rings for Wales. As all the timbers could clearly be seen to come from one phase of construction, an average date range was calculated for all of them. Taking into account the 15 sapwood rings on sample isaf6, this range was found to be 1540-1565, which correlates with the sixteenth century architectural features observed in the building.

### **Acknowledgements**

Thanks go to Fred Foskett, the owner, for allowing access to his building and for his help during sampling and to the other dendrochronologists who allowed their reference chronologies to be used in this report.

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Oxford Dendrochronology Laboratory Report **2009/23**

## Explanation of terms used in table 1

The summary table gives most of the salient results of the dendrochronological process. For ease in quickly referring to various types of information, these have all been presented in Table 1. The information includes the following categories:

**Sample number** Generally, each site is given a two or three letter identifying prefix code. after which each timber is given an individual number. If a timber is sampled twice, or if two timbers were noted at time of sampling as having clearly originated from the same tree, then they are given suffixes 'a', 'b', etc. Where a core sample has broken, with no clear overlap between segments, these are differentiated by a further suffix '1', '2". etc.

**Type** shows whether the sample was from a core 'c', or a section or slice from a timber 's'. Sometimes photographs are used 'p', or timbers measured in situ with a graticule 'g'.

**Timber and position** column details each timber sampled along with a location reference. This will usually refer to a bay or truss number, or relate to compass points or to a reference drawing.

**Dates AD .spanning** gives the first and last measured ring dates of the sequence (if dated),

**H/S bdry** is the date of the heartwood/sapwood transition or boundary (if present), This date is critical in determining an estimated felling date range if the sapwood is not complete to the bark edge.

**Sapwood complement** gives the number of sapwood tings The tree starts growing in the spring during which time the earlywood is produced also known also as spring growth, This consists of between one & three decreasing spring vessels and is noted as *Spring* felling and i indicated by a  $1/4$  C alter the number of sapwood ring count Sometimes this can be more accurately pinpointed to very early spring when just a few spring vessels are visible. After the spring growing season, the latewood or summer growth commences, and is differentiated front the preceding spring growth by the dense band of tissue. This summer growth continues until just before the leaves drop, in about October Trees felled during this period are noted as *summer felled* ( $1/2$  C), but it is difficult to be too precise, as the width of the latewood can be variable, and it can be difficult to distinguish whether a tree stopped growing in autumn or winter. When the summer growth band is clearly complete, then the tree would have been felled during the dormant winter period, as shown by a single C. Sometimes a sample will clearly have complete sapwood, but due either to slight abrasion at the point of coring, or extremely narrow growth rings, it is impossible to determine the season of felling,

**Number of rings:** The total number of measured rings present on the samples analysed.

**Mean ring width:** This, simply put, is the sum total of all the individual ring widths, divided by the number of rings, giving an average ring width for the series.

**Mean sensitivity:** A statistic measuring the mean percentage, or relative, change from each measured yearly ring value to the next; that is, the average relative difference from one ring width to the next, calculated by dividing the absolute value of the differences between each pair of measurements by the average of the paired measurements, then averaging the quotients for all pairs in the tree ring series (Frills 1976). Sensitivity is a dendrochronological term referring to the presence of ring width variability in the radial direction within a tree which indicates the growth response of a particular tree is "sensitive" to variations in climate, as opposed to complacency.

***Standard deviation:*** The mean scatter of a population of numbers from the population mean. The square root of the variance, which is itself the square of the mean scatter of a statistical population of number's from the population mean (Fritts W76).

***Felling seasons and date ranges*** is probably the most important column of the summary table. Here the actual telling dates and seasons are given for each dated sample (it complete sapwood is present) Sometimes it will be noticed that often the precise telling dates will vary within several years of each other. Unless there is supporting archaeological evidence suggesting different phases, all this would indicate is either stockpiling of timber, or of trees which have been levelled or died at varying times but not cut up until the commencement of the particular building operations in question. When presented with varying precise felling dates, one should always take the Latest test date for the structure under study, and it is likely that construction will have been completed for ordinary vernacular buildings within twelve or eighteen months from this latest felling date (Miles 2006),

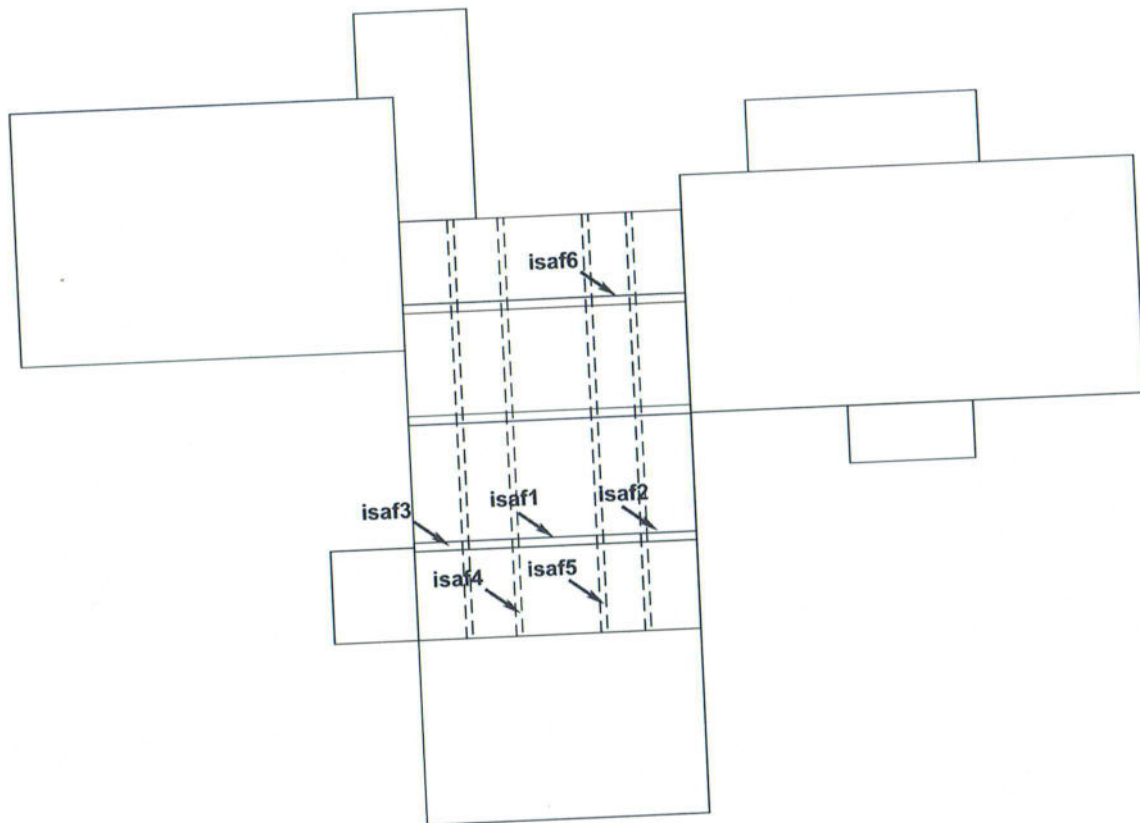
Felling date ranges are produced using an empirical estimates using the appropriate estimate (Miles 1997), However, these can sometimes be reduced using a new sapwood estimation methodology which uses the mean ring width, number of heartwood rings, known ll/S boundary date, and the number of surviving sapwood rings, it present (Miles 2006), These are used after the empirical range and are shown in brackets ( )xCal Followed by date range). Combined felling date ranges for a phase of buildings is shown at the end of the phase to which it relates.

**Table 1:** Summary of Tree-Ring Dating**LLANFAIR-ISAF, HARLECH, GWYNEDD, WALES**

Sample number & type	Timber and position	Dates AD spanning	H/S bdry	Sapwood complement	No of rings	Mean width mm	Std devn mm	Mean sens mm	Felling seasons and dates/date ranges (AD)
isaf1	c Collar t3	-		2	88	2.16	0.79	0.261	
isaf2	c Upper collar t3	-		h/s bry	49	3.14	2.05	0.258	
* isaf3	c Principal rafter w side t3	1438-1519	1519	h/s bry	82	2.04	0.64	0.224	1530-1560
isaf4a	c Upper purlin w side t3-t4	1416-1530	1528	2	115	1.82	0.77	0.219	
isaf4b	c ditto	1510-1526		h/w only	17	1.72	0.33	0.124	
* isaf4	m Mean of isaf4a + isaf4b	1416-1530	1528	h/s bry	115	1.81	0.77	0.217	1539-1569
* isaf5	c Upper purlin e side t4-t5 reset	1452-1517	1517	h/s bry	66	1.79	0.71	0.284	1541-1571
* isaf6	c East principal rafter t1	1426-1526	1525	1+14nm	101	2.08	0.66	0.241	1540-1567
<b>* = ISAF Site Master</b>		<b>1416-1530</b>			<b>115</b>	<b>2.02</b>	<b>0.66</b>	<b>0.196</b>	<b>Average date range 1540-1565</b>
isaf11a	c Cross-beam ex-situ	-			62	1.67	0.94	0.295	
isaf11b	c ditto	-			47	1.27	0.52	0.260	
isaf12	c Staircase timber ex-situ	-			89	1.40	0.43	0.238	

Key: \*, †, § = sample included in site-master; c = core; mc = micro-core; s = slice/section; g = graticule; p = photograph; ¼C, ½C, C = bark edge present, partial or complete ring; ¼C = spring (last partial ring not measured), ½C = summer/autumn (last partial ring not measured), or C = winter felling (ring measured); H/S bdry = heartwood/sapwood boundary - last heartwood ring date; std devn = standard deviation; mean sens = mean sensitivity





**Figure 2.** Diagram showing location of timbers sampled.

**Table 2:** Matrix of *t*-values and overlaps for same-timber means and

## Components of site master ISAF

<i>Sample:</i>	<b>isaf4</b>	<b>isaf5</b>	<b>isaf6</b>
<i>Last ring</i>	1530	1517	1526
<i>date AD:</i>			
<b>isaf3</b>	<u>5.50</u>	<u>4.98</u>	<u>4.48</u>
1519	82	66	82
	<b>isaf4</b>	<u>7.81</u>	<u>5.23</u>
		66	101
		<b>isaf5</b>	<u>3.58</u>
			66

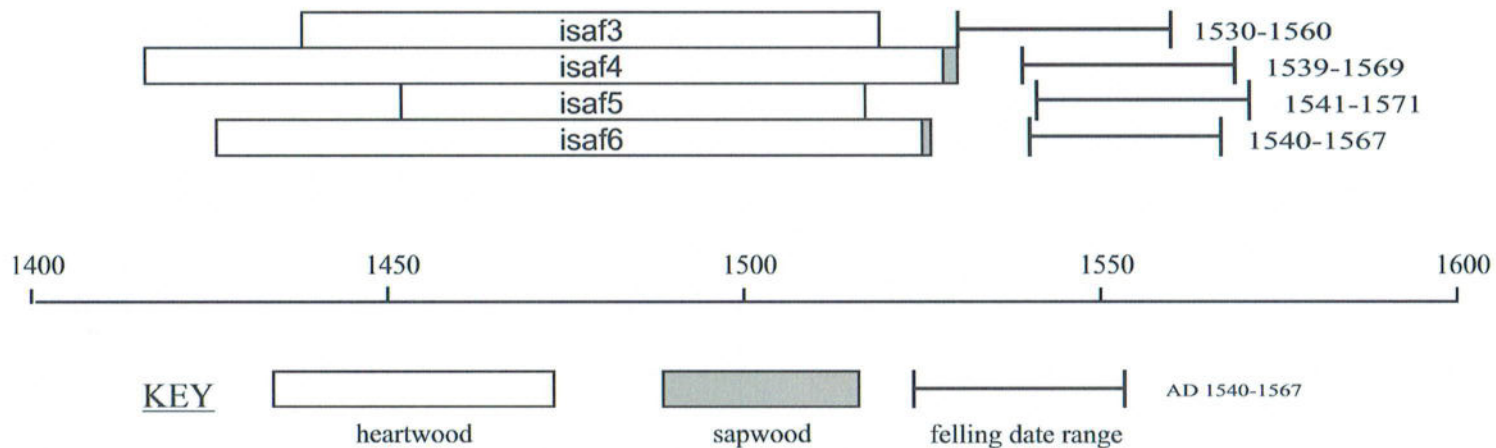
**Table 3:** Dating of site master **ISAF** (1416-1530) against reference chronologies at 1530

<i>County or region:</i>	<i>Chronology name:</i>	<i>Short publication reference:</i>	<i>File name:</i>	<i>Spanning:</i>	<i>Overlap:</i>	<i>t-value:</i>
Gwynedd, Wales	Plas Tan-y-Bwlch, Maentwrog	<i>(Miles, Worthington &amp; Bridge 2006)</i>	BDGLRT23	1411-1535	115	8.22
Gwynedd, Wales	St Brothen's Church, Llanfrothen	<i>(Miles, Worthington &amp; Bridge 2006)</i>	BDGLRT16	1410-1495	80	8.31
Gwynedd, Wales	Parc Llanfrothen	<i>(Miles, Worthington &amp; Bridge 2006)</i>	BDGLRT22	1386-1669	115	8.37
Gwynedd, Wales	Llanfrothen,	<i>(Miles, Worthington &amp; Bridge 2006)</i>	BDGLRT7	1386-1547	115	8.66
~ Denbighshire	Branas Uchaf, Llandrillo	<i>(Miles and Worthington 2010)</i>	DENBY6	1388-1763	115	9.08
Montgomeryshire	Royal House, Machynlleth	<i>(Miles, Worthington &amp; Bridge 2004)</i>	ROYALHS1	1363-1560	115	9.12
Denbighshire	County master chronology	<i>(Miles and Worthington 2010)</i>	<b>SDENBY09</b>	1373-1763	115	9.33
~ Denbighshire	Ucheldref, Rhug, Corwen	<i>(Miles and Worthington 2010)</i>	DENBY4	1373-1597	115	9.52
Denbighshire	Rose and Crown, Gwydwn	<i>(Miles and Worthington 2000)</i>	GWYDWN	1411-1571	115	9.87
Wales	Welsh Master Chronology	<i>(Miles 1997)</i>	<b>WALES97</b>	404-1981	115	10.19
Merioneth	Cefn Caer Pennel	<i>(Miles and Worthington 1999)</i>	CEFNCARI	1404-1525	110	11.85

~ = Component of SDENBY09

Chronologies in **bold** denote regional masters

## Llanfair Isaf



**Figure 3.** Bar diagram showing dated timbers in chronological position