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# The radiocarbon chronology of the Navan excavations.

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CHAPTER 10

# *The radiocarbon chronology of the Navan excavations*

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## PART 1: PRINCIPLES AND METHODS

### Introduction

This Chapter examines the 43 radiocarbon dates from the excavations, all but three obtained from samples submitted by D M Waterman. The dates are subject to a rigorous scrutiny and are analysed in terms of their stratigraphic relationships and in terms of the types and contexts of the sample material. The contribution of the dates to the chronology of the excavations is suggested in the light of the analysis and interpretation.

Forty samples were used to give 43 radiocarbon dates covering all the main phases of site B and the early and late phases of site A (see Date-lists at end of the Chapter).[1] At the time of the excavation and for some time thereafter the status of radiocarbon dating as a direct, simple, relatively precise and absolute dating method was universally accepted. A large number of samples was presented for dating because it was felt that these would provide a detailed chronology of the phases, sub-phases and features of the site. Indeed the dates obtained seemed to be, according to the simple methodology of interpretation then commonplace, clearly in accord with the general chronological trend of the artifacts in suggesting that phases 3 and 4 ran between the later part of the Bronze Age and the earlier part of the Iron Age — about the 8th to the 3rd centuries BC.

The placing of both the ring-ditch, 3(i), and ring-slots, 3(ii–iii), into the same general phase by the excavator is evidence of his commitment to this interpretation, which has been followed by most commentators since. It was a beguiling interpretation as it suggested a continuity of occupation, and of house type (as the southern ring-slots may be interpreted), spanning the obscure transition between the Bronze and Iron Ages. Navan has, therefore, been seen as the key to this transition and as the likely provider of key evidence for the mechanisms by which the early Iron Age arose.[2]

Two advances shook this optimistic view and have necessitated a radical rethink of the chronology. The first was the dendrochronological dating of the central post of the multi-ring timber structure (phase 4) to 95 BC (Baillie 1986; 1988) and the second was the realization and demonstration that a raw radiocarbon date of a sample was a very different thing from an absolute date for a context.[3] The reinterpretation of the dates suggested below gives us a rather different picture of the chronology of Navan from that which has held sway for the last twenty years, but one that may be more in accord with other evidence.[4] It is also clear from the analysis that while radiocarbon dating can be a crucial tool for prehistoric dating when subjected to rigorous interpretation, it can be misleading when interpreted in a simplistic fashion.

### The Principles

Most of the technical problems of radiocarbon dates, and suggestions for their solution, have been widely published (for example Mook and Waterbolk 1985; Taylor 1987; Bowman 1990), but because controversy still surrounds the subject of date manipulation and interpretation it seems wise to summarize the relevant arguments here. I will use a stratigraphic interpretative method that requires explanation at some length.

#### A Radiocarbon Date

A radiocarbon date is the 'age' of a sample of organic origin estimated from the proportion of the radioactive isotope carbon-14 present in that sample. This isotope was originally taken up by the living parent organism and incorporated into the sample with the stable isotopes of carbon (carbon-12 and carbon-13) in roughly the same proportions as were present in the atmosphere at that time. Radioactive decay of this isotope, and thus the continuous decrease of its relative proportion, proceeds from the time of 'death' of the sample (not necessarily the same as the time of death of the parent organism — see the section on 'the old-wood effect', below). After adjustments are made for some sample properties and laboratory conditions and procedures, the 'conventional' radiocarbon date is released by the laboratory.

### The Conventional Date

This is given in the form M ± sd BP, where M is the *mean* of the measurement, sd is the *standard deviation* and BP means *years before 'present'* (AD 1950).[5] This being for all intents and purposes a *normal* or *gaussian* statistic, we may refer to the simple probabilistic property of such — that there is a 95% chance (19 out of 20) that the true value of the 'age' lies within two standard deviations either side of the mean.[6] The conventional dates are listed in Date-list 1, and are summarized in tabular and visual forms in Date-list 2 and Fig 73 respectively.

### Laboratory Errors and Other Adjustments

One complication that is relatively easy to compensate for is the fact that the different metabolic pathways of different organisms treat the carbon isotopes differently, resulting in slight changes to their proportions. This *isotopic fractionation* in the sample can be measured and a calculation made to allow for its effect on the date. For a number of the Navan samples (those where a precise value of $\delta^{13}C$ is given in Date-list 1) the measurement has been done by the dating laboratory, and the quoted conventional date incorporates the correction. In all other cases I have provided an estimate (in parenthesis) of the fractionation value based on the mean for its species and, while the conventional dates in Date-list 1 have not been changed to include the estimate, the dates in Date-lists 2 and 3 have been adjusted.

It has, since the Navan samples were dated, been confirmed that many laboratories have routinely underestimated potential measuring errors, owing to over-confidence in the procedures and equipment. It is presently proposed (Scott *et al* 1983) that, unless the laboratory has already taken this problem into account, the unknown errors should be compensated for by multiplying the standard deviation (sd) by an

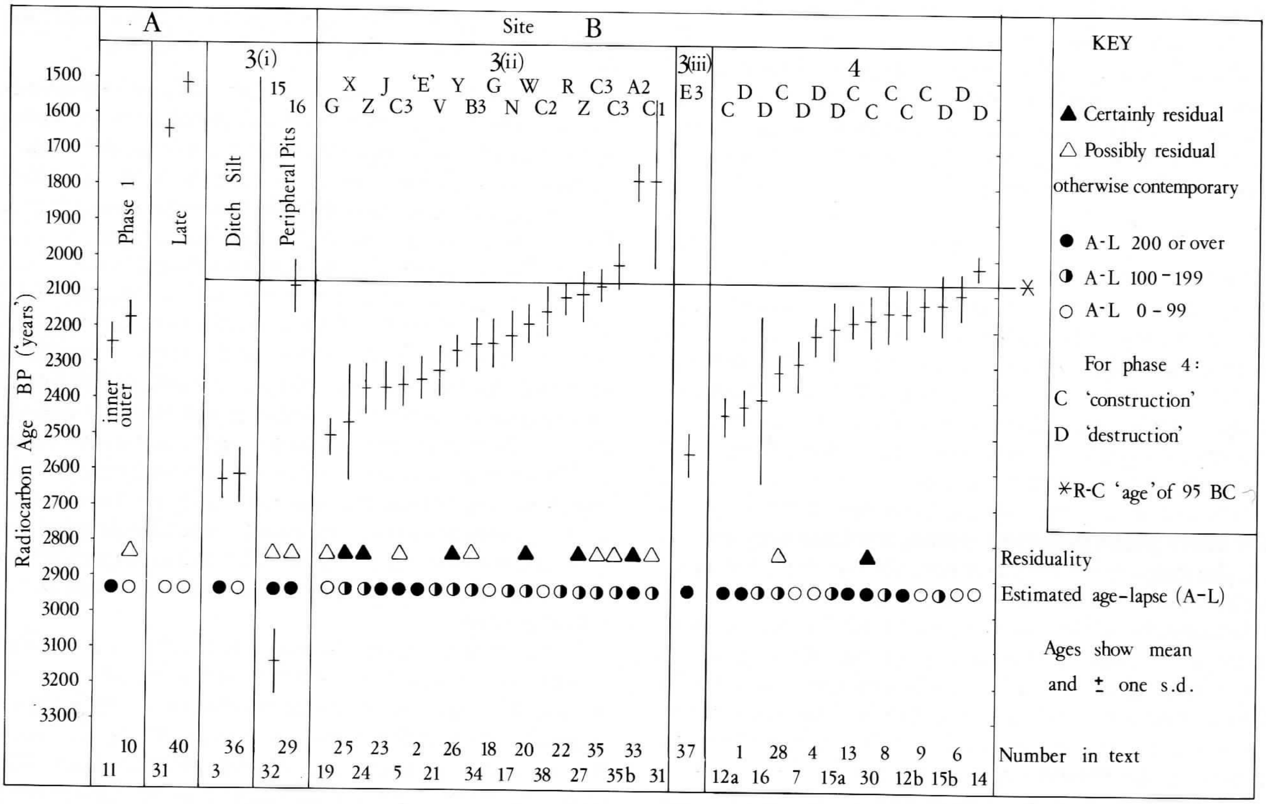


Fig 73 Conventional radiocarbon dates: summary chart

appropriate factor — the *error multiplier*. An error multiplier of 1.5 will be used here for all dates up to, and including, date **37**,[7] and the standard deviations listed as sd* in Date-list 3 have been so adjusted. Sd* is used for all statistical analyses and for calibration.

### CALIBRATION

It has long been clear that the actual proportion of carbon-14 in the atmosphere varied over time. Therefore the radiocarbon date of a sample (which is calculated on the assumption of a constant atmospheric carbon-14 proportion) was likely to be different from its absolute date. The relationship between the two is not uniform but, as a consequence of the careful radiocarbon dating of dendrochronologically dated wood, calibration curves have been produced. These allow an absolute date to be obtained, or 'read off', for any radiocarbon 'date'. More strictly, because of the nature of both the radiocarbon measurement and the fluctuations of the curve they allow a real-date *range* to be obtained for each radiocarbon date. Several procedures have been proposed to effect this calibration — some simple and others complex.[8] I have used the simplest, which gives a *calibrated date-range* (Figs 74 and 75).[9]

The calibrated date-range is quoted in the form 'earliest limit–latest limit BC/AD', and simply means that there is a 95% probability that the absolute date of the sample lies between those limits. The calibrated date-ranges are listed in Date-list 3 ('range 1') and are summarised visually in Fig 76. Throughout the text a date with BP appended will be an adjusted but uncalibrated date (M ± sd*) in radiocarbon years. A date or date-range with BC or AD has been calibrated, and is in real years.[10]

### THE OLD-WOOD EFFECT

Only the living part of a plant, that is the present year's growth (the leaves and outermost ring in the case of a tree), incorporates within its substance the carbon derived that year from the atmosphere. In other words, only the living and growing portion of the plant has, we might say, the radiocarbon date corresponding to that particular year. All other parts of the plant are, organically speaking, dead. Clearly, for some plant materials (grass, for instance) almost all the growth is contemporary and of the time of its collection. It is, however, obvious that the wood of a mature tree spans the time between its first growth year (its centre) and its year of cutting (the ring below the bark). Each annual growth ring has, then, a different radiocarbon date, the latest (the outermost) having the date of the cutting down of the tree (the death of the whole organism) and the earliest (the innermost) having the date of the 'birth' of the tree. In short, the radiocarbon date of a sample of wood derived from a mature tree is the mean date at which that sample grew, not the date at which the tree was cut down. I will call this 'life' age the *organic age* of the sample.

This organic age can, within the material available to archaeologists, be anything from zero to the greatest possible age of that type of plant in the appropriate environment. Any type of organism, or sample deriving from it, has a *maximum likely* organic age and I will call the estimate of this the *age-lapse* (Warner 1976; 1990). For grass the age-lapse is zero and for Irish oak it is about 250 years (or possibly more, see below). Moreover, certain types of samples from long-lived organisms may have demonstrably small organic ages (twigs and leaves for instance) and I will allow for this by giving such types a far smaller age-lapse estimate than the parent organism. All samples may therefore be placed into one of three groups:

*short-life* — material that can be shown to have a small organic age (such as grass and twigs, and most terrestrial animal matter);
*known-life* — material which is not short-life but whose relationship to its cutting-date can be measured on the sample;
*long-life* — material *whose organic age is unknown*, and is therefore potentially large. This is, in effect, any material that cannot be shown to be short-life or known-life and must include all material simply called 'charcoal'. Where the type of tree can be identified a maximum possible age (the age-lapse) may be estimated.

It follows from this that any organically old sample is older than its cutting-date, and possibly even older again than its 'archaeological' use and burial context. It also follows that this difference between sample-date and cutting-/context-date could be considerable (sometimes up to 250 years) and could profoundly effect the interpretation of the radiocarbon date. This potential organic age problem is called the *old-wood effect*. Archaeologists almost always assume that the old-wood effect is minimal and ignore it in their interpretations,[11] except when it can be called upon to explain an 'aberrant' radiocarbon date. It can be shown, however (for instance using the dates from the Navan multi-ring timber structure, below), that the effect cannot be ignored, and indeed is likely to be both present and substantial in a significant number of samples (Warner 1990). The effect must be allowed for if the sample-dates are to be converted to cutting-dates.

In the case of short-life material no old-wood effect is present, and no adjustment or allowance is required. For known-life material the whole date-range should be moved towards the present by the estimated mean organic age of the sample. Long-life material presents a more difficult (and far commoner) problem for which an empirical correction is avail-

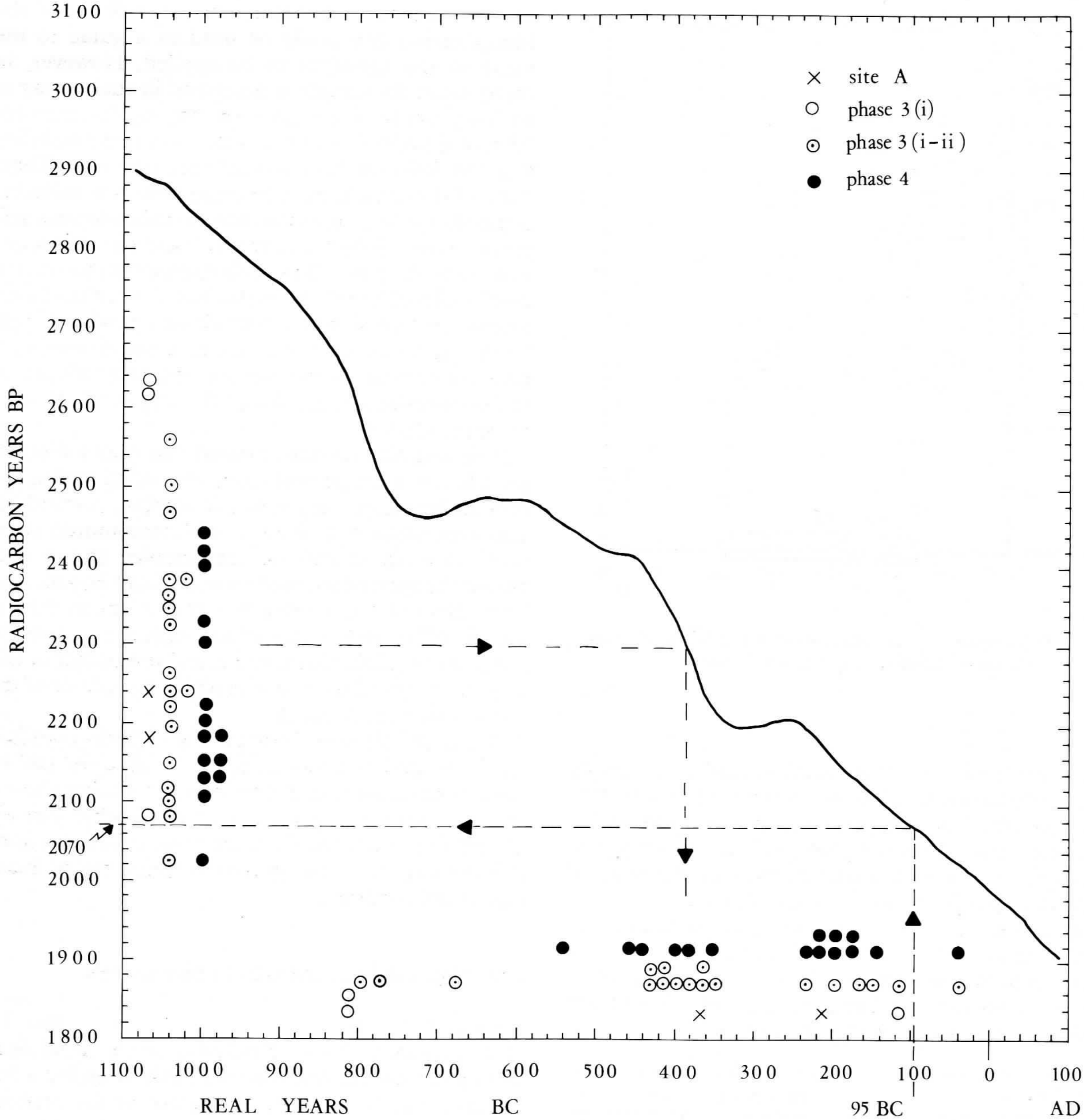


FIG 74 Calibration of the date means using the curve of Stuiver and Pearson (1986)

able (Warner 1990). Unfortunately it is not possible to decide whether any particular long-life sample is suffering from the effect so it must be assumed that all such samples *might* be subject to it. But neither is it allowable simply to assume its maximum presence. At present the only method of allowing for the old-wood effect is to *spread* the date-range, after calibration, by an amount whose size depends on the estimate of age-lapse and on the adjusted standard deviation of the sample.[12] This has the effect of moving the older limit slightly towards the present and the later limit more significantly so. It therefore widens the probability range. When the adjustment has been made we end up with a 95% probability for the cutting-date in real years.[13] The estimated cutting-date ranges are listed in Date-list 3 (range 2) and are summarized visually in Fig 77.

The old-wood-adjusted date-range is quoted in the

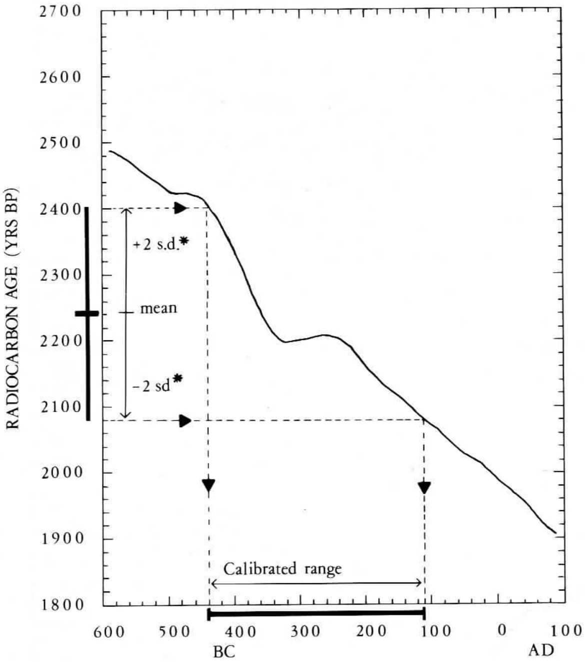


FIG 75 Calibration of the radiocarbon date 2240 ± 80 using the curve of Stuiver and Pearson (1986)

form 'earliest limit – latest limit BC / AD', and simply means that there is a 95% probability that the absolute *cutting-date* of the sample lies between those limits. The following old-wood principle will be employed: *an appropriate correction must be made for the potential old-wood effect in the case of all long-life samples.*

The values used for age-lapse, applicable to charcoal and wood[14] (see 'Identification of sample nature', below), are given in Table 23. The age-lapses for each sample are listed in Date-list 3 and are summarized visually in Figs 73 and 76.

| **Wood type** | **Age-lapse estimate** |
|---|---|
| oak | 250 years |
| unidentified | 250 years |
| ash | 150 years |
| alder, birch | 100 years |
| hazel | 50 years |
| branch | one quarter of the above |
| twigs and straw | 0 years |
| identified mix | compromise value |

Table 24: Age-lapse estimates for samples of wood or charcoal

IDENTIFICATION OF SAMPLE NATURE

Sample identification was undertaken by the dating laboratory.[15] In some cases it is clear that a single-piece sample, for example 'plank' or 'timber', had been identified and dated, and in such cases the identification can safely be used as a guide to the value of the age-lapse to be applied. However, in many cases the sample is described in such a way as to leave doubt about its total nature, for example 'charcoal (alder)', and raises the very real possibility that the identification was of part (the identifiable part) of the sample only. In these cases it is probably unjustifiable to assume that the identification is a safe guide to the value of the age-lapse and we are obliged to assume the possibility of contamination by 'worst-case' material (oak). In such cases (identified by an asterisk in Date-list 2) I have chosen a value of age-lapse that seems to be a reasonable compromise between identification and 'worst case'. At certain places in the discussion of the dates this caution will be seen to be justified.[16]

It should also be remembered that only a discrete sample has a single real date, contained within the probability range. Any multiple sample, particularly that type often described as of 'comminuted charcoal', is likely to contain sub-samples of any date within the span of the context and of any organic age. The 'date' of the sample is a sort of mean for the sample (Warner 1976), and although the probability range will contain this mean it will not reflect in any way the range of dates of the whole sample or of the context that produced it.

Where the old-wood adjustment is inadequate (too small an age-lapse was estimated) a date will still be too old for its context. A date is far less likely to be too late (see also 'the principle of residuality' below). Therefore, *where two dates are irreconcilable the latest will normally be given preference* (principle of inadequate adjustment).

## Stratigraphic Analysis of the Dates

CONTEXT

Considerations of the individual contexts of the dates will be left for the discussion of those contexts. I will indicate, on the basis of the nature of the context, whether samples should be considered to be *contemporary* (first deposited during the life of the context) or *residual* (incorporated into the context through disturbance of an older context). Unrecognized intrusion of a sample from a later context or misassignment by the excavator would both seem to be unlikely. I will make no attempt to quantify the time for which a sample is likely to have been in *use* before burial. The following principle of residuality will apply (see above, p 152 for justification): *where two dates are irreconcilable the latest is more likely to reflect the context-date* (see also 'the principle of inadequate adjustment', above).

The principle of residuality applies particularly to the fill of the slots, therefore: *unless the material in the*

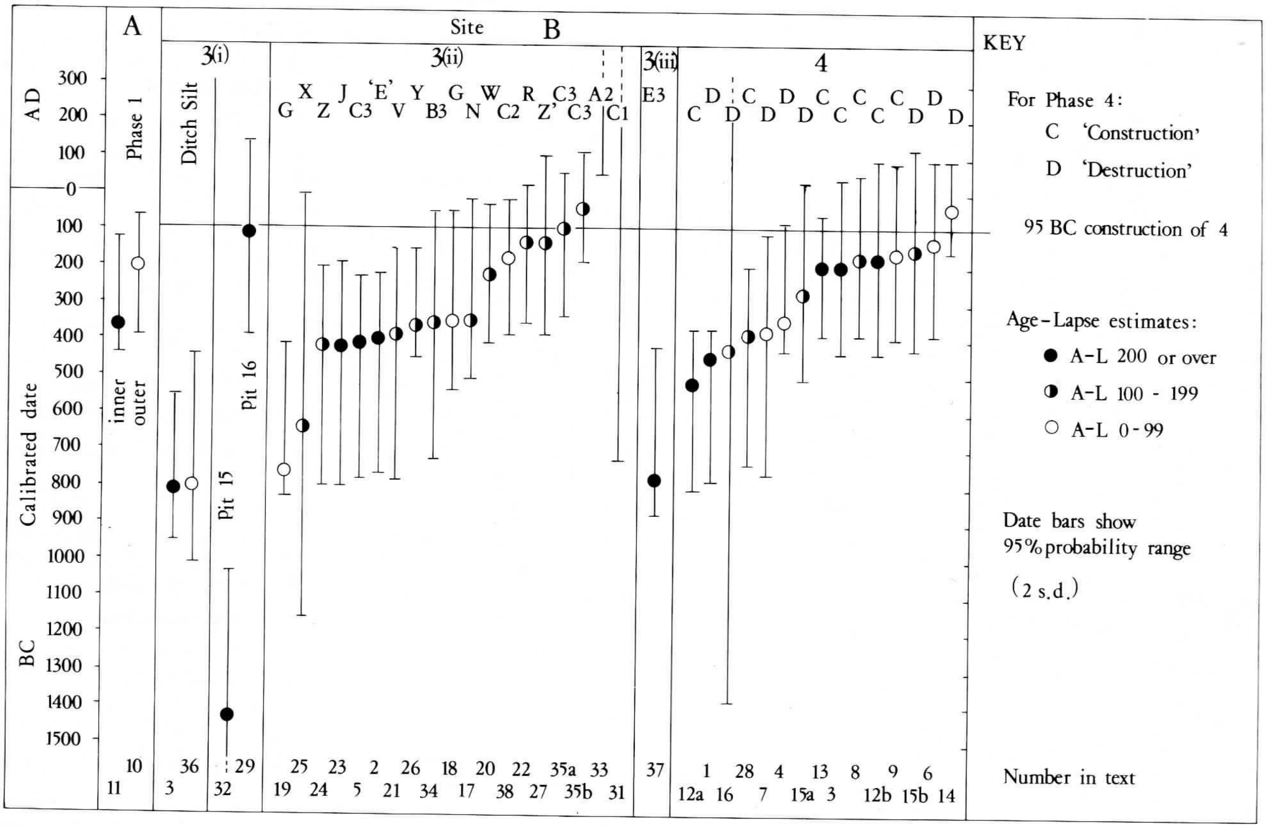

Fig 76 Calibrated sample-dates: summary chart

*fill of a slot can be shown to be contemporary, for instance structural, it will be assumed to have derived from an older context.*

Context date-ranges are listed in Date-list 3 (range 2), and summarized visually in Fig 77 and its derivatives by the use of a symbol (>) or letter (r) to indicate possible or probable residuality (no symbol and the letter c indicate probable contemporaneity). In other words, where contemporaneity of sample and context have been assumed the context-date and cutting-date are the same. Where residuality has been thought probable the context-date is an unknown amount later than the cutting-date. The context date-ranges are used in the main discussion.

## The Analytical Method

The analysis of the chronology of the site depends heavily on the stratigraphy of the dates. In some cases the stratigraphic information is helped by conclusions that can be drawn about the *span* of each phase or sub-phase (or event). I identify two kinds of *phase-span*: a *short-span* phase is one whose span is likely to be small compared with the probability range — typically over 250 years — of a calibrated radiocarbon date.

Clearly an *event* (such as a construction) is short-span, and we are surely justified in assuming that a wooden house-life (as the southern ring-slots may be interpreted) is also short-span. Conversely, a *long-span* phase is one which *cannot be shown to be short-span.*

The methodology that I will use in the discussion of the stratified dates has been discussed at length elsewhere (Warner 1976), but the principles, which are applied primarily to the *boundaries* of the phases, sub-phases or events, can be summarized here (see Fig 78A):

the date of a stratigraphic boundary is unlikely to be significantly earlier than the *latest lower (older) limit* of all the dates below that boundary. This limit gives us the (probable) lower limit of the boundary, which I shall refer to as the *boundary lower limit (*BLL*)*;

the date of a stratigraphic boundary is unlikely to be significantly later than the *earliest upper (later) limit* of all dates above that boundary. This limit gives us the (probable) upper limit of the boundary, which I shall refer to as the *boundary upper limit (*BUL*)*.

Where dates exist above and below a boundary that

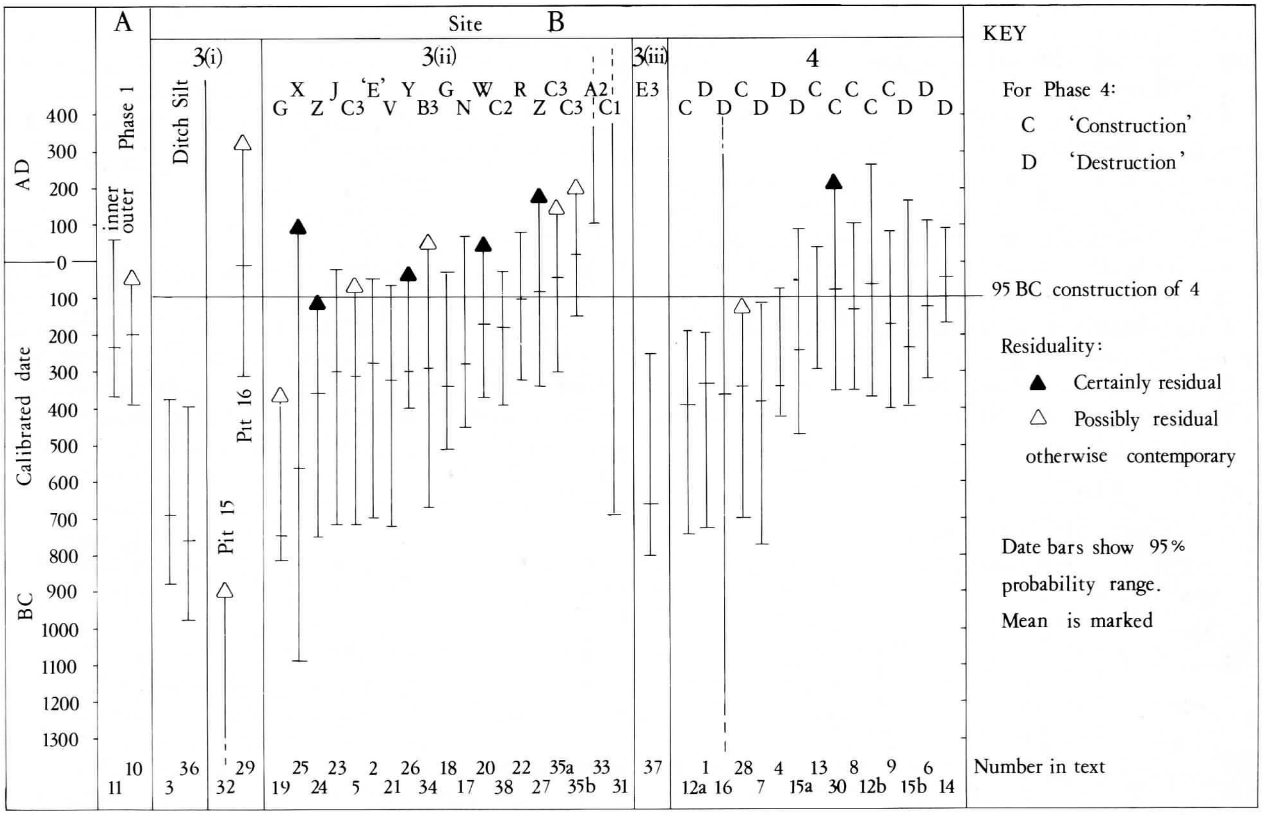


FIG 77 Calibrated context-dates: summary chart

boundary has both an upper and a lower limit, from which we obtain a *probable range* (BR) for the boundary — the range from the lower limit to the upper limit of that boundary.

From the probable ranges of the lower and upper boundaries (LBR and UBR) of a phase, sub-phase or event we obtain the probable ranges of the phases, sub-phases or events thus bounded — the minimum and maximum ranges being the inner and outer pair of boundary dates respectively. In other words, the phase began within the range of its lower boundary and ended within the range of its upper boundary (see Fig 78B). The ranges of the upper and lower boundaries of a short-span phase will be assumed to be the same, within our acceptable chronological limits of precision (a half-century or so).

Some of the assumptions above may appear rather pessimistic, but we must remember that the radiocarbon method gives a coarse chronology. Unjustified claims of precision are to be avoided and I will suggest a chronology only as detailed as radiocarbon properly allows. Although Date-list 3 gives precise (nearest decade) ranges I will interpret the results in a more flexible fashion.[17]

## PART 2: THE CHRONOLOGY

### Introduction

Date-list 1, at the end of this Chapter, lists the dates with laboratory number, conventional (unadjusted) mean and standard deviation, isotopic fractionation value, sample type and context details. Against each date is a number, from **1** to **40**, used (in bold type) throughout the discussion. This information is tabulated more conveniently in Date-list 2. In Date-list 3 the dates are listed by phase and here we find running number, context (and sample type), 95% calibrated range (with no correction for old-wood effect but with the error multiplier applied), estimate of age-lapse, calibrated range corrected for old-wood effect and estimate of deposition status (residual or contemporary). Figure 74 shows the distribution of the dates before and after calibration.

The 95% value for probability used leads to the expectation that one or two dates will not include the real date within their stated range. We cannot and should not try to guess which dates are wrong on a superficial inspection, but we might expect them to show up as grossly inconsistent in the analysis. For instance, date **33** is impossibly late for its context and contradicts every other date obtained. As it is probably a statistical exception I will not use it in the analysis (see below).

To recap, in all the following analyses, the old-wood correction has been applied, as appropriate, to all the dates. The estimated age-lapse for each, with which the old-wood correction has been calculated, is shown in Date-list 3. The date-range used throughout the analysis is tabulated in column 'range 2' of that list. It must be remembered that this range represents the span of real years in which the cutting-date lies with a 95% probability, but with an extra identifier to show how it may be read as the context-date.

The phases are considered in contra-chronological order because we have a single fixed date provided by the dendrochronological dating of the central post (that is the construction of the multi-ring timber structure of phase 4) to 95 BC (Baillie 1986; 1988) and it is, therefore, convenient to analyse the dates for that structure first.

## Phase 4

The excavator recognised four sub-phases associated with the multi-ring timber structure — construction of the wooden frame; construction of the lower part of the mound; destruction by fire of the wooden frame; completion of the mound. These are the constituents of phases 4 and 5, subsequent use of the

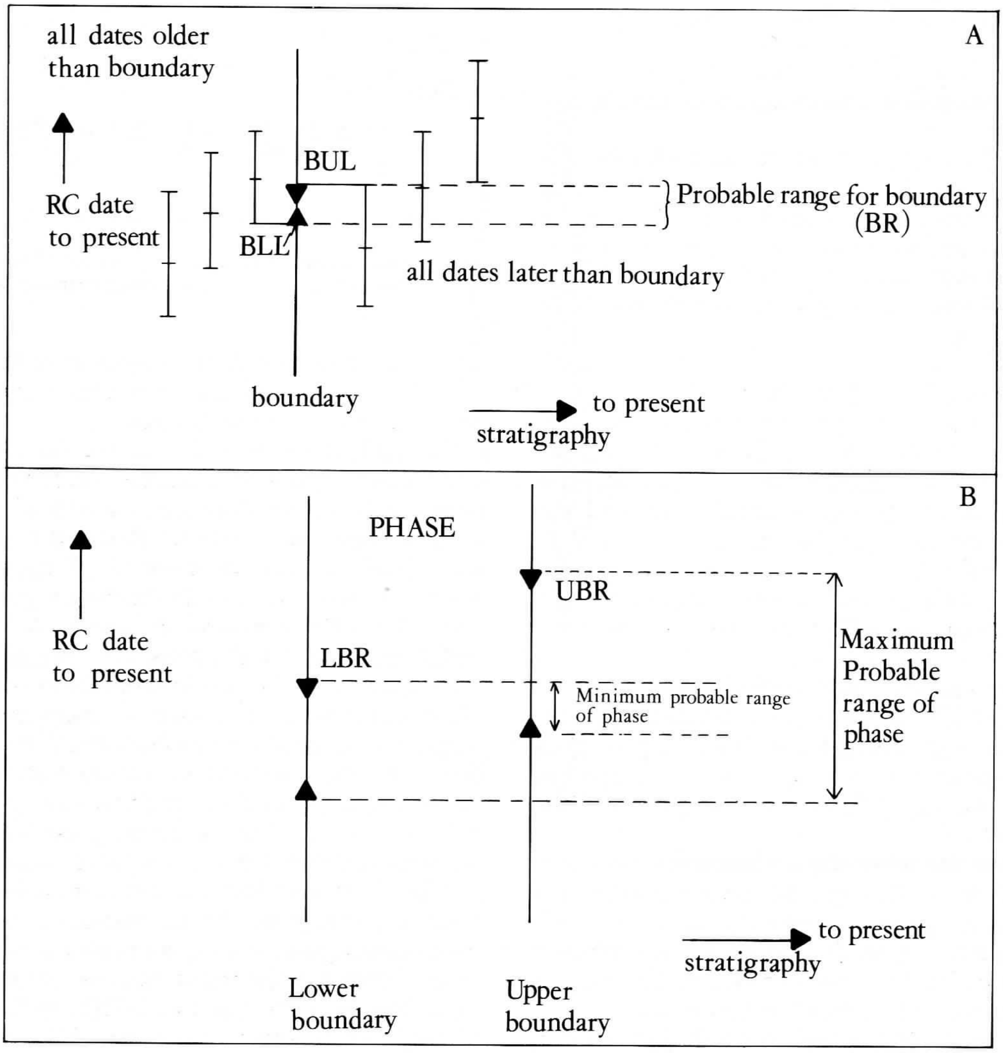


FIG 78 Stratigraphic analysis of radiocarbon dates: A, derivation of boundary range (BR) from the boundary lower limit (BLL) and the boundary upper limit (BUL); B, derivation of the maximum and minimum probable ranges of a phase from the probable ranges of upper (UBR) and lower (LBR) boundary ranges

mound not being included in the analysis. It remains the argued view of the editor that the time-scale over which all these happened was very short — short, that is, in the way I have earlier defined 'short-span'. The excavator selected samples for dating both from the construction phase (the posts and their packing) and the destruction phase (burnt material around the periphery of the site). This labelling is followed although it seems possible that at least some of the 'destruction' material was actually material from the wooden building itself. I accept the probability that the construction and destruction events were both short-span, but I will not assume, except in discussion of the null-hypothesis below, that the period between the events was insignificant.

The fifteen samples (Figs 79 and 82) fall into the three typological groups, short-, known- and long-life, according to the identifications, as follows:

(i) short-life (age-lapse less than 100 years): there are four samples in this category, all having contemporary status;
(ii) known-life: there are two samples, both with contemporary status; one derives from the dendrochronologically-dated central post;
(iii) long-life material: there are nine such samples, two of which might be residual; some have a medium level of age-lapse and several the maximum 250 years.

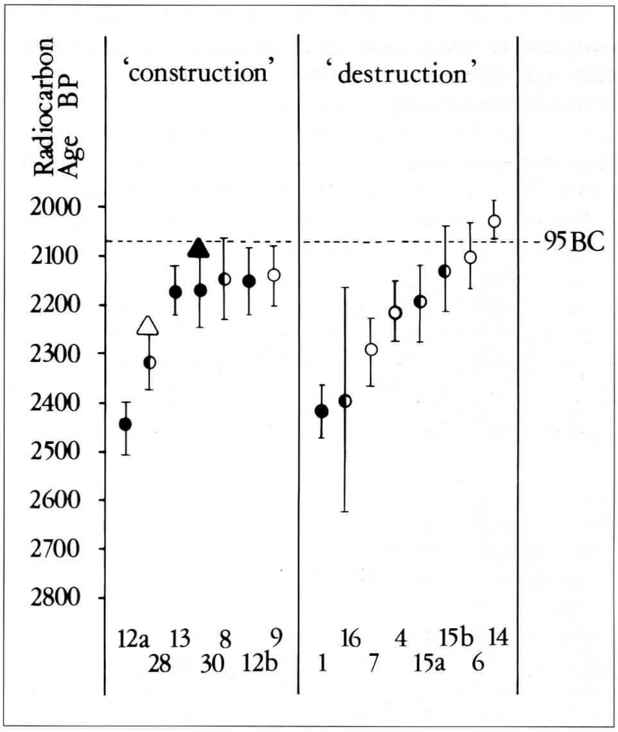


FIG 79 Conventional radiocarbon dates for phase 4 multi-ring timber structure: summary chart (symbols as Fig 73)

STATISTICAL ANALYSES OF THE PHASE 4 DATES

The fifteen samples from phase 4 *should* be contextually indistinguishable from the known date of that phase — 95 BC. We might therefore expect that the sample-dates would be independent assessments of that known date. However, as the following analysis shows, they do not, at their face value, fit such an interpretation and only by recognizing the importance of the old-wood effect may we reconcile samples and event.

I shall postulate, and subsequently test, the null-hypothesis: NH(1) — *the sample-dates are independent estimates of a single date,* and, if this is supported, a second null-hypothesis: NH(2) — *the sample-dates are independent estimates of the known date of phase 4 construction — 95 BC.*

I shall make the following assumptions, on which the null-hypotheses depend: the old-wood effect has not affected any dates significantly (in other words the sample-dates are the cutting-dates), and phase 4 represents a single short-span event and the samples from it are structurally related to that event.

We may analyse the sample-dates in radiocarbon years without calibrating them, for the samples should all have, under the null-hypotheses of being independent estimates of a single radiocarbon date, the same radiocarbon age. Thus we may take advantage of the 'normal' statistical properties of the radiocarbon dates and avoid the extra errors and complications introduced by calibration.

For NH(1) we assume that we do not know the actual date of phase 4. A simple test has been devised whereby the probability that a group of dates represents independent measurements of a single target date (NH(1)) can be assessed (Ward and Wilson 1978). When our sample-dates are tested on this procedure they produce a probability so low that the null-hypothesis NH(1) must be rejected.[18] In other words, the spread of the sample-dates is too wide to allow them to be regarded as measurements of a single target date. This could occur if we had underestimated the potential laboratory errors. If we had applied a larger error multiplier, say 2.0 instead of 1.5, NH(1) might have been supported. However, as we shall see, this is not an acceptable explanation.

The Ward and Wilson test, although statistically rigorous, compares the sample-dates against their own pooled group mean, not against an independent measurement of the target date, as we possess in this case. Strictly, having shown NH(1) to be untenable, NH(2) falls. However, it is easy and instructive to test NH(2) also. A simple modification of the Ward and Wilson test replaces the pooled mean by the known context-date of 2070 ± 20 BP (the reverse-calibration of 95 BC, see below). Using this test the rejection of

NH(2) is overwhelming.[19] There is, however, no significant statistical difference between the construction and destruction groups of dates.

We note that there is a very strong oldward bias to the phase 4 date set. Of the fifteen means only one is later than the known date of phase 4, and the weighted mean of these dates is 130 ± 30 radiocarbon years too old.

We may provisionally postulate several explanations for the failure of the null-hypotheses.

*Explanation 1 — the archaeological interpretation of the contexts is faulty (the samples are mostly residual).* There is absolutely no reason to believe that any samples have been misassigned. Samples **28** and **30** are the only ones likely to be residual and of these only **28** is unacceptably old. This explanation must be rejected.

*Explanation 2 — laboratory errors were underestimated.* An underestimate of the error multiplier might explain the scatter; it will not explain the bias. A systematic bias caused by laboratory procedure can be ruled out both by laboratory checks of known-date samples and for the following reason. The same procedure in the same laboratory was responsible for the calibration curve from which the reverse-calibration of the known phase 4 date was derived. Had there been a systematic bias it would have affected the reverse-calibration equally and would, therefore, have been invisible.

*Explanation 3 — the spread and bias are caused by the old-wood effect.* This possibility will be discussed below.

These phase 4 dates will be considered in more detail in order to try to explain the failure of the null-hypotheses. The radiocarbon equivalent of the known date of construction of phase 4 (95 BC), obtained by reverse-calibration on the chart of Stuiver and Pearson (1986), is 2070 ± 20 BP. This should be the radiocarbon date of any sample growing in that year and, assuming those propositions under which I framed my null-hypotheses, it also ought to be the value of which the fifteen sample-dates are independent estimates. The deviations (dev) of the means of the sample-dates (radiocarbon years) from the radiocarbon equivalent of the known real date (dev = m − 2070) should be accounted for by the statistical variation of that deviation, as measured by its standard error (se).[20] Each deviation may be normalized by dividing it by its standard error, giving a value z. By the rules of gaussian statistics one would expect, under NH(2), these z values to be normally distributed around zero with a variance of 1. In other words, one would expect about two-thirds of the values to lie between z = +1 and −1, and only one in 20 to lie outside the range +2 to −2. One would also expect the mean of z to be statistically indistinguishable from zero, with roughly equal numbers either side of zero (a positive deviation is older than the known date, a negative is later).

The values of z for the phase 4 dates are tabulated in Table 25 and are illustrated in Fig 80, which also shows the expected distribution of z. We note that although there is a peak close to the expected mean there is also a long tail whose z values are significantly and improbably high. The failure of the observations to match the expectation is visually striking (and we already know that the null-hypothesis is unsupportable). We may consider this distribution in the light of the old-wood effect. I have indicated on the figure my estimates for the age-lapse of each sample, which are, of course, based only on the sample description. We see that the degree of deviation closely correlates with the value of the age-lapse; for instance, the samples with small age-lapse concentrate, in gaussian fashion, close to expectation, half the samples with long age-lapse fall significantly early, and the samples with medium age-lapse have a trend between these extremes. We note that three out of four of the samples whose absolute z value exceeds 2 (the 95% probability limit) have a significant age-lapse value and are, therefore, probably suffering from a signifi-

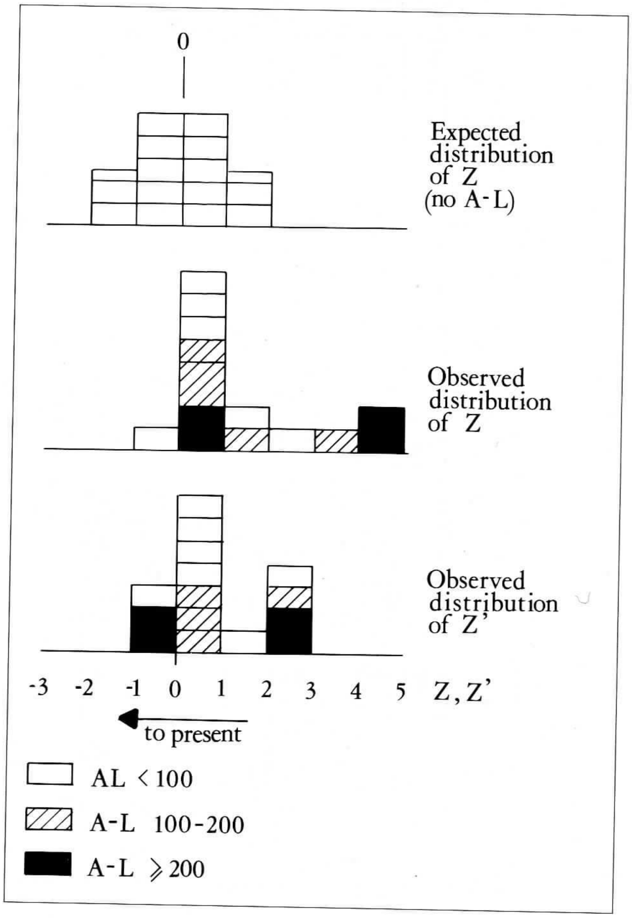


FIG 80 Phase 4: expected distribution and observed deviation of z and z′ values from 2070 BP

cant old-wood effect, and that the two extreme samples are of the highest age-lapse type. Finally we note again the positive bias, almost all the dates being older than the mean. These are precisely the expectations of an active old-wood effect.

We may now 'adjust' the means for estimated age-lapse as follows. From each mean we subtract half the value of its age-lapse (we are 'correcting' for the 'mean' old-wood effect, each sample mean being moved towards the present by that amount).[21] We recalculate z as z′; thus m′=m–(a-l)/2, dev′=m′–2070, z′=dev′/se′. Clearly the samples with greater age-lapse will be pulled towards the present by a greater amount than those with small age-lapse. Were the sample distribution not correlated with age-lapse the distribution of z′ would show a shift towards zero mean and a slight lessening of the variance, but one would not expect the histogram to be normalized or the different age-lapse groups to become balanced within it. As Table 25 and Fig 80 show, the z′ distri-

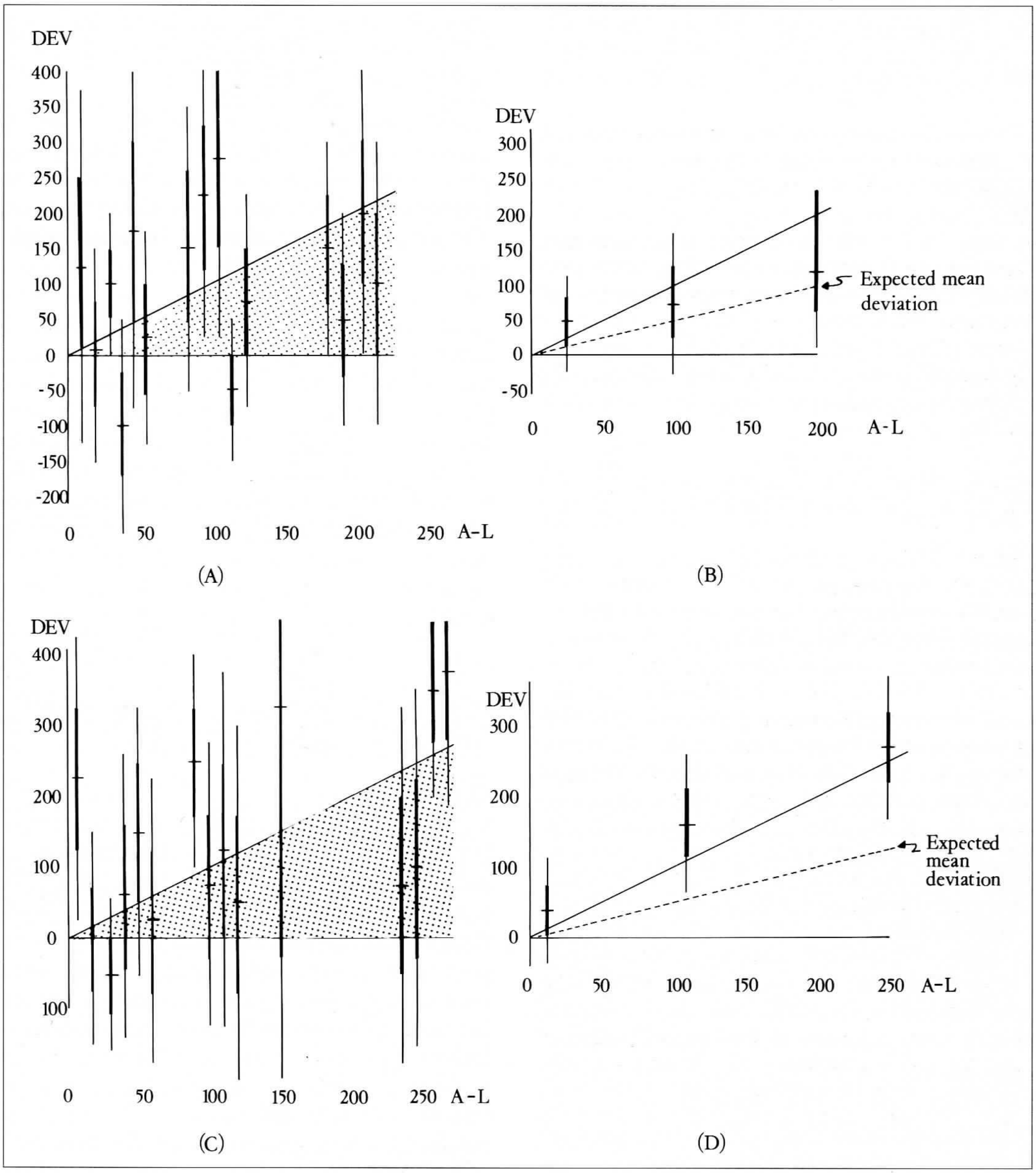


Fig 81 Phase 4 dates: A, simulated values (plotted to ± 2 sd, age-lapse triangle stippled), B; weighted-mean deviations of the simulated dates (gathered into short, medium and long age-lapse groups); C and D - the same for the actual phase 4 dates

bution fits the expected (normal) distribution quite well, the variance is unity and the different age-lapse groups are uncorrelated to deviation.

Furthermore, if we apply the Ward and Wilson test to these age-lapse adjusted means (mean′, se′) we find that NH(1) is now accepted and NH(2) is only marginally rejected.[22] The weighted mean of these age-lapse-adjusted dates is 2135 ± 25 BP, which is not significantly different from our known date of 2070 ± 20 BP. The construction and destruction groups of dates are statistically indistinguishable, having weighted-adjusted-means of 2145 ± 35 and 2130 ± 35. They are also indistinguishable from the known date of 2070 ± 20, NH(2) being accepted for each group individually.[23]

| no | mean | dev | se | z | a-l | m′ | dev′ | se′ | z′ |
|---|---|---|---|---|---|---|---|---|---|
| 12a | 2440 | 370 | 90 | 4.3 | 250 | 2315 | 245 | 110 | 2.2 |
| 1 | 2415 | 345 | 80 | 4.4 | 250 | 2295 | 220 | 100 | 2.2 |
| 16 | 2395 | 325 | 350 | 0.9 | 150 | 2320 | 250 | 350 | 0.7 |
| 28 | 2315 | 245 | 80 | 3.1 | 100 | 2265 | 195 | 85 | 2.3 |
| 7 | 2295 | 225 | 110 | 2.1 | 0 | 2295 | 225 | 110 | 2.1 |
| 4 | 2215 | 145 | 90 | 1.6 | 20 | 2205 | 135 | 90 | 1.5 |
| 15a | 2195 | 125 | 120 | 1.0 | 100 | 2145 | 75 | 125 | 0.6 |
| 30 | 2170 | 100 | 120 | 0.9 | 250 | 2045 | −25 | 135 | −0.2 |
| 12b | 2150 | 80 | 120 | 0.7 | 250 | 2025 | −45 | 135 | −0.3 |
| 8 | 2150 | 80 | 110 | 0.7 | 100 | 2100 | 30 | 115 | 0.3 |
| 9* | 2125 | 55 | 110 | 0.5 | 0 | 2125 | 55 | 110 | 0.5 |
| 15b | 2125 | 55 | 130 | 0.4 | 200 | 2025 | 5 | 140 | 0 |
| 6 | 2100 | 30 | 100 | 0.3 | 50 | 2075 | 5 | 100 | 0 |
| 13* | 2075 | 5 | 75 | 0 | 0 | 2075 | 5 | 75 | 0 |
| 14 | 2020 | −50 | 60 | −0.8 | 0 | 2020 | −50 | 60 | −0.8 |
| w.m. | 2190 | | | | | 2135 | | | |
| mean **z** (exp 0) | | | | 1.4 | | | | | 0.8 |
| var **z** (exp 1) | | | | 2.2 | | | | | 1.1 |

Table 25: Deviations from the known date of phase 4
(* These deviations have been adjusted using the known age-lapse of the sample)

Clearly, if we accept the reality of the old-wood effect, we may make several predictions. We must expect that the samples tend to be older than their context. We must expect a tendency for samples of long-life type to be older than contemporaneously deposited samples of short-life type. We must, therefore, expect a tendency for the positive deviation from the known date of the context to be correlated to the age-lapse. With reference to Fig 81A, at two standard deviations most samples should extend into the triangle formed between the line dev=(a-l) and the line dev=0. Furthermore, the weighted means of the age-lapse groups should tend to fall near the line dev=(a-l)/2. Figure 81A and 81B shows the results of a computer-generated simulation of dates with the same spread of standard deviations and age-lapses as the actual phase 4 dates. The simulated deviations obey these predictions.

On Fig 81C and 81D we see the actual phase 4 dates plotted in the same way as the simulated dates. The sample distribution almost obeys the overlap rule. The weighted-mean distribution follows the correct trend — a linear correlation between dev and (a-l), but the slope is steeper than expected.[24] The correlation confirms the belief that the old-wood effect is a major influence on the dates and must be taken into account. Its steepness, however, requires explanation, the most likely cause being that the samples mostly tended to be organically old parts of the source tree — an important observation in the old-wood debate. But it is also possible that the age-lapse values suggested to me by the botanical and dendrochronological experts, and listed above, should be larger, perhaps by a factor of 2.

Following these results we may reapply the two null-hypotheses to the same three age-lapse groups. NH(1) and NH(2) are rejected for the five phase 4 samples with large age-lapse, NH(1) is accepted but NH(2) rejected for the four samples with medium age-lapse, and both NH(1) and NH(2) are accepted for the six samples with short age-lapse.[25] The weighted mean of the last group, 2105 ± 30, is statistically indistinguishable from the known date of 2070. These results are very good confirmation of the old-wood effect, its likely values and the need to allow for it. Adjustment for the effect must be universal and *a priori*, for nothing about sample context would justify one in making corrections only to those dates one did not like. Reconciliation has been successful using the age-lapse values listed. Using smaller values or ignoring the old-wood effect would have made reconciliation completely impossible.

## Stratigraphical Analysis of the Phase 4 Dates (see Fig 82)

*Construction*

Using the stratigraphic analytical principles outlined earlier we find that the limits of the lower boundary are defined by dates **35b** (BLL = about 150 BC) and **1** and **12a** (BUL = about 200 BC) (Figs 77 and 82). Although these limits are reversed they are close and, giving extra weight to the limit associated with **35b** (as we should), suggest a lower boundary range (LBR) of the later 2nd century BC. Similarly **35b** and **1** give us identical limits, and an identical range, for the upper boundary as we would anyhow have argued for a short-span phase. It can be concluded, therefore, on the radiocarbon evidence, that: *the date of construction of the multi-ring timber structure was about the latter half of the 2nd century BC*. This is completely in accord with the known (dendrochronological) date of 95 BC.

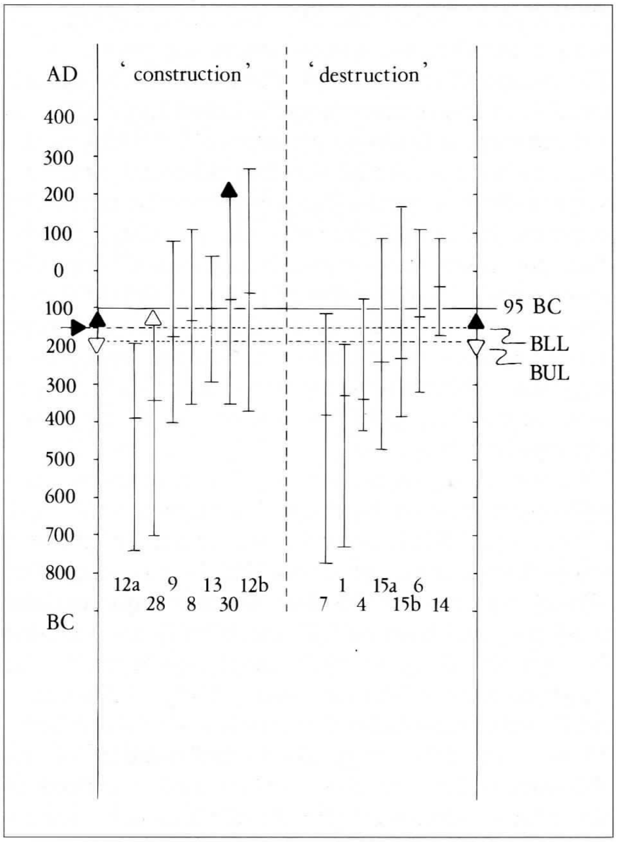


FIG 82 Calibrated context-dates for phase 4, showing upper and lower limits of the boundary between construction and destruction

It is clear, given the dendrochronological date of construction, that the upper limits of dates **1** and **12a** are about a century too early. It would be useful to know why these dates are too old by such an amount. In the first place we have adduced 'principles' that advise us that dates that are too old are less problematic than dates that are too late. The causes of this one-way bias may be inadequate age-lapse adjustment or residuality. Residuality in the proper sense of the sample having derived accidentally from an earlier context is not a possible explanation here, the aberrant (early) samples being wooden post-packing and destruction charcoal from the perimeter, but we cannot be completely sure that these samples were not wood *reused* from earlier structures. As to inadequate age-lapse adjustment: as one sample is described as 'oak charcoal' and the other as 'timber' they have both been given the largest allowable age-lapse. However, we may have underestimated the likely maximum possible age of oak. We should also bear in mind that all dates have a 5% chance of lying outside our 95% probability range, and that our error multiplier adjustment may be too small. Whatever the explanation, I do not regard the century discrepancy as serious. Rather it confirms my belief that we should not normally argue for greater precision than a century from radiocarbon evidence.

*Destruction*

The limits of the lower boundary are defined by dates **35b** and **1** so that they and the LBR are the same as those of the UBR for construction. For the upper boundary the BLL is defined by **35b** and **14** at about 150 BC, but there are no post-boundary dates to give us the BUL. However, on the principle that a short-span phase has the same upper and lower boundary ranges we can say that the UBR should be the same as the LBR. Therefore (as already indicated in the statistical analysis): *the date of the destruction of the multi-ring timber structure is not significantly (or measurably) different from that of the construction.*

## Phases 3(ii) and (iii)

Phases 3(ii) and 3(iii) provided twenty radiocarbon dates from a wide selection of their features (Figs 83 and 84). One of these dates (**33**) must be excluded from the analysis as it is completely unacceptable. It comes from an early 3(ii) ring-slot, and its loss to us is serious for that reason, but it falls so much later than the known date of phase 4 that no amount of statistical manipulation can make it acceptable. Of the remaining nineteen dates, eighteen are from 3(ii) and one from 3(iii). Eight dates relate to southern ring-slots (mostly those of the C sub-phase), seven relate to the northern ring-slots, and four to the entrance palisade-slots.

The nineteen samples fall into the two typological groups, short- and long-life, according to the identifications, as follows.

i) Short-life material (age-lapse less than 100 years). There are three samples in this category, two having contemporary status.

ii) Long-life material. There are sixteen such samples. Twelve have a medium level of age-lapse and only three the maximum 200–250 years.

Eight of the samples can be described as contemporary and the other eleven as probably or possibly residual. The samples from the northern ring-slots mostly fall into the former category, and those from the southern ring-slots and palisaded entrance mostly into the latter.

STATISTICAL ANALYSIS OF THE PHASE 3(ii–iii) DATES

Figure 85 shows the number of samples whose means fall in each radiocarbon century, indicating their estimated age-lapses. The first histogram, Fig 85a, shows all site B dates (excluding **33**). It will be seen that there is a clear tendency for the dates with the longest age-lapses to decrease in their proportion towards the

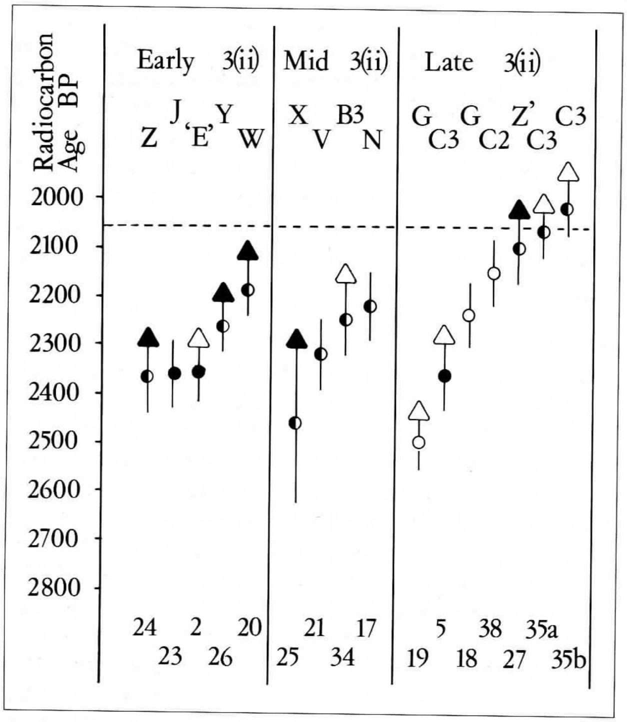


FIG 83 Phase 3(ii) conventional radiocarbon dates: summary chart (symbols as in Fig 73)

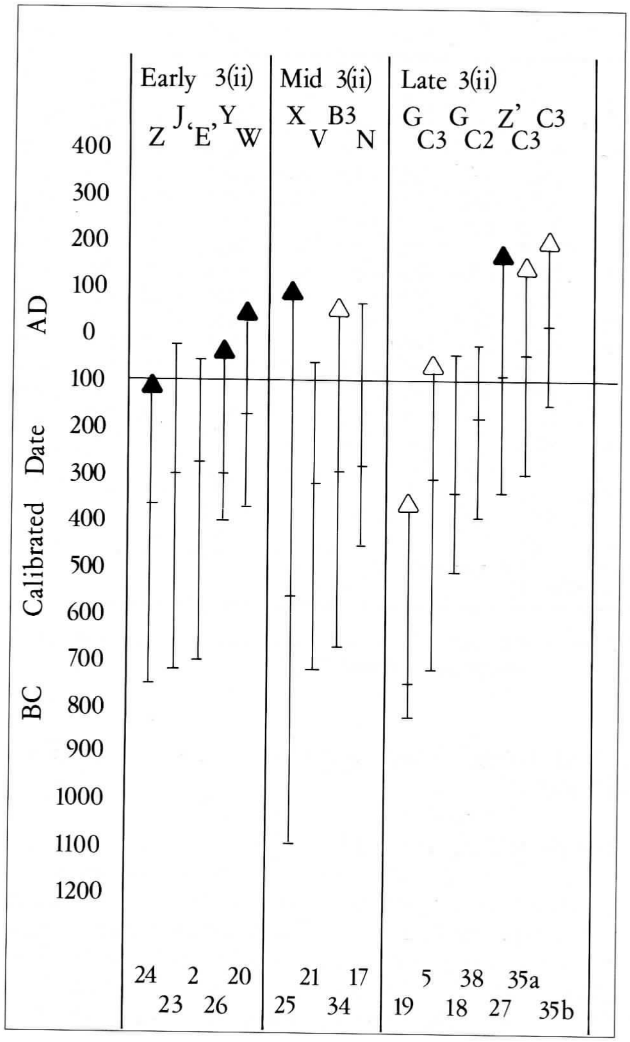


FIG 84 Phase 3(ii) calibrated context dates: summary chart

present, whereas those with medium and short age-lapses increase. This is a quite predictable result of the old-wood effect, already demonstrated by the 'z-histograms' of phase 4. Fig 85b shows the samples for sub-phases 3(ii) and 3(iii) only, and the old-wood trend is very clear. This should immediately suggest to us that the older dates are strongly influenced by the effect, and that we are quite justified (as we have already shown for phase 4) in assuming that the effect must be allowed for in all samples, as dictated only by their type. This histogram indicates that the contexts from which the samples are drawn belong, in the main, to the 23rd and 22nd centuries BP. This is supported by the almost gaussian shape of Fig 85b, implying a relatively short period of deposition, though clearly not quite as short nor as late as phase 4, as Fig 85c shows.

When we repeat the Ward and Wilson analysis on the conventional dates the null-hypothesis NH(1) is overwhelmingly rejected. We now adjust the mean of each date for its average age-lapse exactly as we did for the phase 4 samples to obtain its m′and sd′, and we find that NH(1) is just rejected at the 1% level.[26] If we apply our z-value analysis (Table 26) the results are most interesting, as Fig 86 shows. The unadjusted (z) histogram shows, as expected, the high age-lapse samples heavily biased towards the past. The adjusted (z′) histogram shows, again as expected, a far better balance for the age-lapse values. This histogram also shows a most remarkable distributional tightness, with a gaussian shape and sharp node that is quite impossible to interpret in any other way than to infer that the time of deposition for 3(ii) and 3(iii) was relatively short — not more than a couple of centuries. The weighted mean of this distribution is 2165 ± 25 BP, which would be about 200 BC.

| no | mean | dev | se | z | a-l | m′ | dev′ | se′ | z′ |
|---|---|---|---|---|---|---|---|---|---|
| 2 | 2345 | 105 | 85 | 1.2 | 250 | 2120 | −45 | 110 | −0.4 |
| 34 | 2245 | 5 | 105 | 0 | 150 | 2170 | 5 | 115 | 0 |
| 31 | 1785 | −455 | 350 | −1.3 | 100 | 1735 | −430 | 350 | −1.2 |
| 38 | 2150 | −90 | 80 | −1.1 | 0 | 2150 | −15 | 80 | −0.2 |
| 5 | 2360 | 120 | 85 | 1.4 | 200 | 2260 | 95 | 105 | 0.9 |
| 35a | 2075 | −165 | 75 | −2.2 | 120 | 2015 | −150 | 80 | −1.9 |
| 35b | 2015 | −225 | 75 | −3.0 | 120 | 1955 | −210 | 80 | −2.6 |
| 20 | 2185 | −55 | 85 | −0.6 | 100 | 2135 | −30 | 95 | −0.3 |
| 21 | 2320 | 80 | 105 | 0.8 | 150 | 2265 | 100 | 115 | 0.9 |
| 17 | 2220 | −20 | 105 | −0.2 | 150 | 2165 | 0 | 115 | 0 |
| 22 | 2110 | −130 | 75 | −1.7 | 100 | 2060 | −105 | 80 | −1.3 |
| 23 | 2365 | 125 | 105 | 1.2 | 250 | 2240 | 75 | 125 | 0.6 |
| 18 | 2240 | 0 | 105 | 0 | 50 | 2215 | 50 | 110 | 0.5 |
| 19 | 2505 | 265 | 80 | 3.3 | 50 | 2480 | 315 | 100 | 3.1 |
| 24 | 2370 | 130 | 105 | 1.2 | 120 | 2310 | 145 | 115 | 1.3 |
| 25 | 2465 | 225 | 240 | 0.9 | 150 | 2390 | 225 | 245 | 0.9 |
| 26 | 2260 | 20 | 75 | 0.3 | 150 | 2185 | 20 | 85 | 0.2 |
| 27 | 2105 | −135 | 105 | −1.3 | 120 | 2055 | −110 | 115 | −0.9 |
| 37 | 2550 | 310 | 95 | 3.3 | 250 | 2425 | 260 | 120 | 2.2 |
| wm | 2240 | | | | | 2165 | | | |
| wsd | 20 | | | | | 25 | | | |
| var **z** (exp 1) | | | | 2.8 | | | | | 1.9 |

Table 26: Deviations from their weighted means of the dates of sub-phases 3(ii) and 3(iii)

## Stratigraphic Analysis of Phase 3(ii–iii) Dates (Figs 77 and 84)

*Sub-phase 3(iii) (slots E1 to E3)*

Only a single date was obtained from this phase, **37** — a contemporary part of the structure E3. The upper boundary is limited by **1** and **12a** (which we have seen above we must replace by 95 BC) and by **35b**. The UBR is therefore the later part of the second century BC. The lower boundary is limited by **35b** and by **37**. Here again we have an inconsistency because the reversed limits are a century apart. Weighting **35b** above **37**, as we must, we conclude that the LBR is also of the (?later part of the) 2nd century BC and that *3(iii) belongs within the (later) 2nd century BC.*

This is not inconsistent with the excavator's belief that phase 4 immediately followed structure E3. As regards the early nature of **37** I would refer the reader to the preceding discussion on the phase 4 discrepancies.

*Sub-phase 3(ii) (all other slots)*

Nineteen dated samples belong to this phase, of which one (**33**) has been disregarded. It will be seen from the figures that the chronological distribution of these phase 3(ii) dates is not very different from that of the phase 4 dates, which we know belong to a short-span event at 95 BC. Furthermore, as will be seen on Fig 84, there is scarcely any visible difference between the dates from 'early' 3(ii) and those from 'late' 3(ii). There is no significant difference between these groups when the Ward and Wilson test is applied. These attributions of slots and contexts to 'early', 'middle' and 'late' 3(ii) are partly stratigraphic (for instance, ring-slots A to C) and partly based on a subjective assessment of the pattern of slots and gulleys (see Chapter 9), and cannot be regarded as certain.

It has already been indicated in the statistical analysis above that it seems unlikely that phase 3(ii) lies any earlier than the 23rd century BP, which is the 4th century BC. It can be shown (see below) that were any substantial part of 3(ii) of Late Bronze Age date (before the 4th century) the expected pattern of radiocarbon dates would be significantly different from that which we have. It should also be noted that of

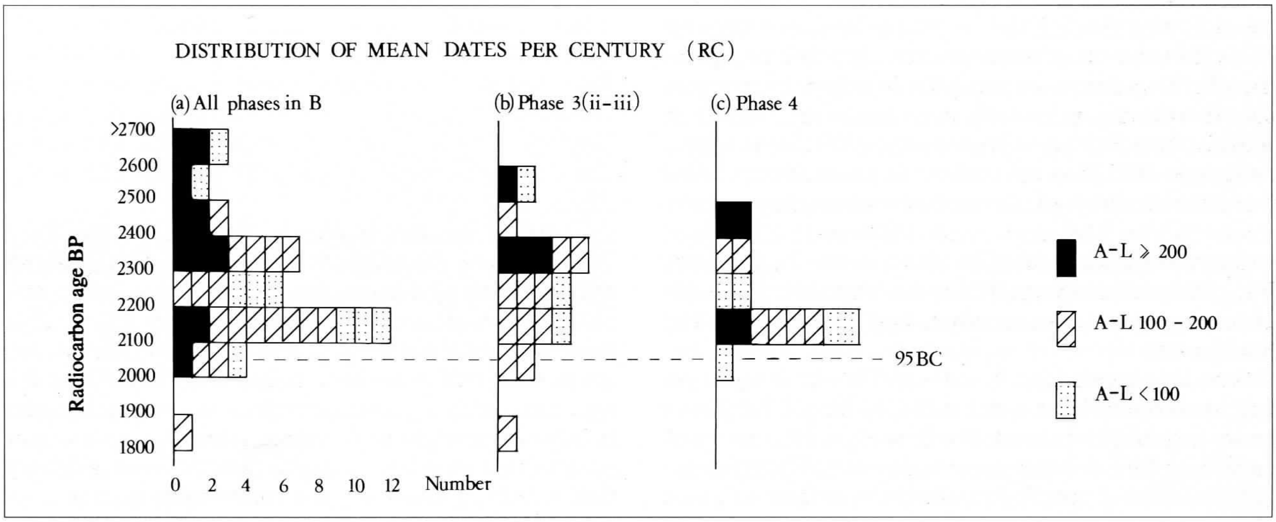


Fig 85 Distribution of phase 3(ii–iii) mean dates per century with indications of likely age-lapse

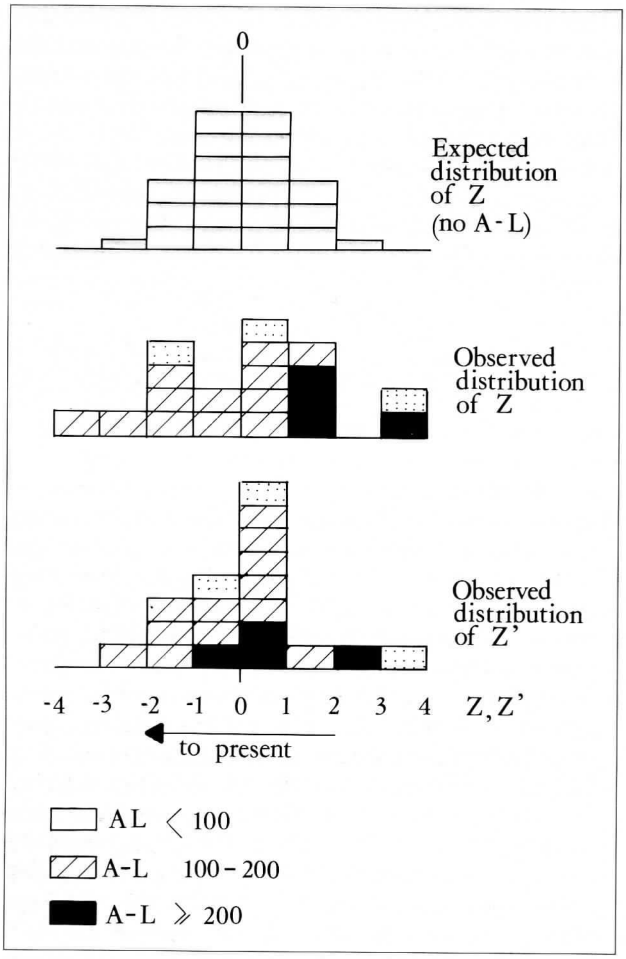


FIG 86 Expected distribution and observed variation of z and z′ values from group weighted means

the eighteen dates used in this analysis of phase 3(ii), eleven can be described as probably or possibly residual. Residuality might mean no more than belonging to a previous sub-phase insignificantly earlier, but it also might imply derivation from the much earlier phase 3(i), or at least contain 3(i) material as a contaminant. Therefore, 3(ii) is more likely to be later than the dates indicate rather than earlier.

The upper boundary range (UBR) of 3(ii) is, of course, the LBR of 3(iii), that is (later ?) 2nd century BC. Sample **35b**, from the latest ring-slot, C3, indicates that late 3(ii) continued until well into the 2nd century and that no significant hiatus existed between 3(ii) and 3(iii).

Date **19** seems to give us the BUL for the lower boundary of 3(ii), about 400 BC. Date **29** appears to provide a BLL for the lower boundary of 3(ii), about 300 BC. These are inconsistent, but as I remarked in the discussion of phase 4 I do not regard an inconsistency of a century as significant. It would appear, therefore, that the date of the lower boundary (the LBR) of 3(ii) is within the 4th century BC. However, **19** is from an apparently late 3(ii) slot, and it, therefore, also gives us a BUL for the beginning of the *later* part of 3(ii). That is, if we accept **19** we must accept that a greater part of phase 3(ii) falls in or before the 4th century BC. This is not overtly contradicted by **20** and **26**, which inform us that early 3(ii) did not begin before the 4th century BC, but it does imply that the middle of 3(ii) was of very short duration while late 3(ii) lasted for a couple of centuries.

Slot G produced two samples — one, **19**, within it and the other, **18**, 'burning contiguous with that in slot G'. The implication is that they are from the same burning layer. *Both* samples were described as hazel, a short-lived wood whose age-lapse we are unlikely to have underestimated. In all other Navan samples containing hazel it was mixed with other woods, as is made clear in the descriptions. In these two samples, *only* hazel was identified. They are, furthermore, 'consistent' with each other in that their ranges overlap in the 5th century BC. If we were able to dismiss **19** completely as residual we could fall back on the BUL of 3(iii) as providing also the BUL of 3(ii), with which all 3(ii) samples would be compatible — within the 2nd century BC. However, the nature of the two samples and the apparent connection of their contexts tell strongly against residuality. Contamination by unrecognized charcoal of a long-lived species must be a more likely possibility for this sample. In this case, if we give **19** a compromise age-lapse of 150 years, our calibrated range becomes 780 BC–310 BC, which is more consistent with **29** and, given the general level of precision I advocate, *marginally* allows a 3rd century date for slot G and for much of phase 3(ii). However, this does not seem to be much more satisfactory than the uncontaminated scenario.

We probably must accept that **19** gives us a BUL for the lower boundary of 3(ii), and that this is not later than the 3rd century BC, and might even be 4th century. We are more reluctant to accept its status as late 3(ii) and we tentatively propose that slot G has been misattributed to late 3(ii) and should be assigned to early 3(ii).

The BLL for 3(ii) is given by **29**, which comes from peripheral pit 16 of phase 3(i). It is, as we shall see below, much later than expected and does not appear to date the pit. The sample *apparently* came from what might have been a 'post-pipe' low in the pit and underneath the jumble of soil and stones filling the pit. The pit had been intersected by the main outer wall-slot of the phase 4 building, but this slot did not reach through these stones to the charcoal. I do not believe that the contents of the slot itself contaminated the sample, but the clear implication is (as we shall see below) that the sample fell into the pit when whatever had been in it was removed. One would suppose this was done sometime between the beginning of phase 3(ii) (as general clearance of the site for the first structures), which is my preferred option, or when the building of phase 4 was put up. Although the date of **29** is quite compatible with this supposition and fits well with the 3(ii) chronology it cannot under this proposition give us the BLL for the lower boundary of 3(ii). This is given, instead, by **3**, as about 900 BC, which, though compatible with **19**, gives us a rather wide LBR of the 9th to the 4th (or 3rd) century BC.

I finally draw attention once more to dates **20**, a residual sample in northern ring-slot W, and **26**, a residual sample in entrance palisade-slot Y. These contexts are described in Chapter 9 as 'early' 3(ii) and their lower limits of the earlier part of the 4th century would strongly militate against a start for 3(ii) very much before that time. In short, I believe we can conclude that *phase 3(ii) began not before the 4th century BC and continued to the end of the 2nd.*

*Sub-phases within 3(ii) and 3(iii)*

As Table 22 (p 150) shows, there are some clear vertical relationships between the ring-slots in the same areas (southern and northern ring-slots), but much less clear linkages between the areas. Sub-phases A2, B3, C1, C2 and C3 produced dates (three from the last). Date **31** from C1 is uninformative and **33** from A2 has been rejected. The stratigraphically proposed sequence B3<C1<C2<C3 is not contradicted by the dates for those features, although we must bear in mind that only the ape skull, date **38**, from C2 is certainly non-residual. The dates for the other slots are also compatible with, but do not refine, the relationships (Y<Z′, J<G, W<V=X) proposed by the excavator.

I have already given my reasons for proposing that slot G should be transferred to early 3(ii). On the basis of the foregoing discussion of the 3(ii) dates I suggest that the early part of 3(ii) should be considered to fall somewhere within the bracket of the 4th to mid-3rd century BC (I prefer the later part of this bracket), the middle part to fall within the 3rd century BC and the later part to fall within the bracket of the later 3rd to mid-2nd century BC. I therefore suggest the following very tentative chronology for the southern ring-slots ('houses'), with the understanding that we might be a half-century too late: *A — earlier 3rd century; B — later 3rd century; C — earlier 2nd century; E — later 2nd century.*

## Phase 3(i)

THE PENANNULAR DITCH (see Fig 77)

Two dates come from the 'primary silt' of the penannular ditch (**3** and **36**). Their conventional radiocarbon dates are statistically indistinguishable, but being both described simply as 'charcoal' we must nonetheless adjust them for the old-wood effect. I take primary silt to be a short-span context which includes the digging of the ditch itself, and, lacking evidence for extensive prior occupation, I accept that residuality is possible but not probable. The overlap of the samples tells us that the ditch was dug and began silting somewhere between the start of the 9th and the start of the 4th century BC. This is not a satisfactory outcome, for the 3(i) ditch could, with this wide uncertainty, pre-date the start of 3(ii) by almost 600 years or by less than a century. We should recall that the ditch was quite substantially filled by the time the first 3(ii) entrance palisade-slots were constructed.

THE PERIPHERAL PITS

No stratigraphic relationship was discovered between the peripheral post-pits and the ditch. Certainly the pits are concentric with the ditch, but so is the very much later multi-ring timber structure of phase 4. Therefore, although it is clear that the pits represented a single-period circular structure it cannot be demonstrated that that structure was constructed at the same time as the ditch was dug. We could equally posit that the structure was built inside a pre-existing ditch, or that the ditch was dug around a pre-existing structure. Two of the pits produced dates: pit 15 gave us **32**, from what is described as 'oak and ash charcoal lining the clay core' (whatever that means) of the pit, and the adjacent pit 16 provided **29**, which is described as 'oak charcoal from dark fill' of the pit.

The dates from these two pits (see Fig 77) are totally incompatible with each other. If one gives us the date of the structure of which the post-pits were contemporary parts the other cannot.[27] However, neither is unacceptably incompatible with the extremes of possibility for the date of the ditch. At its upper limit of about 900 BC **32** is just compatible with the earliest date for the ditch. At its lower limit of about 300 BC **29** is, within our accepted limits of precision, almost compatible with the latest possible date for the ditch. These are, it must be admitted, marginal and unsatisfactory compatibilities, but they may not easily be dismissed. I discussed **29** under the 3(ii) heading and concluded that the charcoal might have intruded during the extraction of whatever structure the pit contained (I rejected the possibility that it was contaminated by the digging of the outer slot for the multi-ring timber structure in phase 4). In other words, a case can be made, but not proved, for the intrusive status of **29**. As for **32** I cannot understand the description of the charcoal context, but I assume that 'lining the clay core' means lining the edge of the central part of the pit (rather than its sloping ramp). In other words, the charcoal entered when whatever the pit originally held was placed in it. This charcoal could therefore have been residual, but from what context I cannot hazard a guess. It seems unlikely that it could have been substantially earlier than the structure.

We have, therefore, a dilemma. One pit produced a sample of after 300 BC that *might* be intrusive. Its neighbour produced a sample of earlier than 900 BC that *might* be residual. No reconciliation is possible, but I would propose that the intrusive nature of **19** is accepted and that the residual nature of **32** is minimized. Therefore, *the penannular ditch dates somewhere between the 9th and the 4th centuries BC; the peripheral pits date somewhere between the 17th and the 8th century BC and, should the ditch and the pits be contemporary, as seems not unlikely, they were probably constructed in the 9th or 8th century.*

## Site A

### The Slots

Two samples come from the triple-slot phase of site A, from the second and third slots. Date **11**, from a burnt plank from the inner, latest, slot, is certainly contemporary. Date **10**, from the outer (middle period) slot, is probably residual. Both samples are extremely similar in date and put the slots within the bracket of the 4th century BC to the 1st century AD. In other words, this triple slot might be the same general date as the slots of phase 3(ii–iii), site B, which it resembles, or slightly later. *The date of the triple-slot phase of site A lies within the range of the 4th century BC to 1st century AD.*

### The Ditch

Two samples of animal bone from a deposit of occupation debris in the ditch of site A were dated (**39** and **40**). There is no reason to doubt their contemporaneity with the deposit in which they lay. The deposit was some way up the ditch and merely serves as a *terminus ante quem* for the cutting of the ditch. We may interpret the dates thus. The *minimum* period for the deposit would be a single discrete event in about the 5th century AD. It could, however, be of far greater span, the only constraint being that the span *included* the 5th century AD.

It is clear, also, that the digging of the site A ditch must be placed between the lower boundary of the pre-ditch slots (see below) and the occupation debris just assessed. The *lower* and *upper* boundaries for the ditch-digging are therefore about 400 BC and AD 450. *The ditch of site A was dug sometime between the 4th century BC and the 5th century AD. Occupation debris was deposited in the ditch in the 5th century AD, and possibly before and after.*

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*Correction*

Since this Chapter was completed the editor has advised me that date **28** is more likely to belong to phase 3 than to phase 4. I had already, within the text, regarded this date's context as questionable, and given it a 'possibly residual' status. Its attribution to phase 3 does not affect the discussion of the chronology of phase 3 and accords with the conclusions. Its removal from phase 4 corrects an anomaly because, as I had observed, it was the *only* date that was unacceptably old, even when allowing for the old-wood effect. The figures and graphs explaining the anomalies of the phase 4 dates as results of the old-wood effect would not be changed significantly by the removal of **28**, nor would the general conclusions. On the contrary, all the arguments have been strengthened.

# PART 3: THE DATE-LISTS

## Date-List 1: The Primary Information

I here list the dates with information gleaned from the editor; from the only published date-list (dates **1** to **5** only — Smith *et al* 1970); from a draft date-list compiled by G Pearson in 1976 for *Radiocarbon* but never published; from the register of dates held by the laboratory; and from other sources such as letters and notes. I include the text reference number; laboratory code (for example UB-186); conventional (quoted) date with standard error; value of isotopic fractionation in per-mil ($\delta^{13}C$), or an estimate in parentheses (see discussion); reference to published date-list (see below); context and sample details (as far as they exist). Where the identification was recorded in the laboratory register, but not in the lists published in, or produced for, *Radiocarbon,* the sample type is in brackets. A summary will be found in Date-list 2. A key to abbreviations used in the Date-lists will be found at the end of Date-list 3. All samples are from site B unless otherwise specified.

**1** UB-186 2413 ± 44 BP $\delta^{13}C$ (–25 ± 1 ‰)
Oak charcoal. From the destruction layer at the periphery of mrts. Phase 4.

**2** UB-187 2347 ± 50 BP $\delta^{13}C$ (–25 ± 1 ‰)
(Charcoal). From 'burning at the base of the old soil above the silting of the ditch'. Probably from phase 3(ii), near the beginning.

**3** UB-188 2628 ± 50 BP $\delta^{13}C$ (–25 ± 1 ‰)
(Charcoal). From the 'primary fill' of the phase 3(i) ditch.

**4** UB-202 2215 ± 50 BP $\delta^{13}C$ (–25 ± 1 ‰)
Charcoal from small branches (including hazel). From above make-up on fill of post-pit. Destruction layer of mrts. Phase 4.

**5** UB-203 2359 ± 50 BP $\delta^{13}C$ (–25 ± 1 ‰)
Charcoal (including ash). From slot C3. Phase 3(ii).

**6** UB-467 2100 ± 60 BP $\delta^{13}C$ (–25 ± 1 ‰)
Carbonized branch. From destruction layer of mrts. Phase 4.

**7** UB-468 2295 ± 70 BP $\delta^{13}C$ –27.4 ± 0.5 ‰
Carbonized fibrous material, 'probably straw'. From destruction layer of mrts. Phase 4.

**8** UB-469 2150 ± 70 BP $\delta^{13}C$ –29.1 ± 0.5 ‰
Cellulose from small twigs (and wood). From packing around central post of mrts. Phase 4, construction.

**9** UB-470 2130 ± 65 BP $\delta^{13}C$ (–25 ± 1 ‰)
Cellulose from 13-year-old branch of birch (with bark). From packing around central post of mrts. Phase 4, construction.

**10** UB-752 2175 ± 45 BP $\delta^{13}C$ –26.0 ± 0.2 ‰
*Site A.* (Twig-like) charcoal of alder. From fill of outermost wall-slot.

**11** UB-770 2240 ± 50 BP $\delta^{13}C$ –23.9 ± 0.2 ‰
*Site A.* Oak charcoal of burnt plank. Actual wall in inner wall-slot.

**12a/b** UB-771 2345 ± 45 BP $\delta^{13}C$ –27.1 ± 0.2 ‰
Charred timber. From packing around central post of mrts. Phase 4, construction. Mean of two dates: 2440 ± 55, 2150 ± 80. These dates will be used separately.

**13** UB-772 2175 ± 45 BP $\delta^{13}C$ –24.8 ± 0.3 ‰
Charred timber. Central post of mrts. Phase 4, construction. About 100 years from outside of post.

**14** UB-773 2020 ± 35 BP $\delta^{13}C$ –24.5 ± 0.2 ‰
Carbonized fibrous material, 'probably straw'. From destruction of mrts. Phase 4.

**15a/b** UB-774 2160 ± 65 BP $\delta^{13}C$ –26.0 ± 0.2 ‰
Carbonized timber of alder. From destruction layer of mrts. Phase 4. Mean of two dates: 2195 ± 80, 2125 ± 85. These dates will be used separately.

**16** UB-775 2395 ± 235 BP $\delta^{13}C$ –24.4 ± 0.2 ‰
Carbonized timber of ash. From destruction layer of mrts. Phase 4.

**17** UB-778 2220 ± 70 BP $\delta^{13}C$ –23.9 ± 0.2 ‰
Carbonized stake of ash. Slot N, phase 3(ii).

**18** UB-780 2240 ± 70 BP $\delta^{13}C$ –24.9 ± 0.2 ‰
Hazel charcoal. From burning contiguous with that in slot G. Phase 3(ii).

**19** UB-781 2505 ± 50 BP $\delta^{13}C$ –24.9 ± 0.2 ‰
(Hazel) charcoal. From slot G. Phase 3(ii).

**20** UB-782 2185 ± 55 BP $\delta^{13}C$ –24.7 ± 0.2 ‰
Ash and hazel charcoal. From fill of slot W. Phase 3(ii).

**21** UB-783 2320 ± 70 BP $\delta^{13}C$ –24.1 ± 0.2 ‰
Ash charcoal from a burnt plank 15 cm wide, some bone in sample. From slot V. Phase 3(ii).

**22** UB-784 2110 ± 45 BP $\delta^{13}C$ –24.5 ± 0.2 ‰
Carbonized alder plank. Found lying lengthways on bottom of slot R. Phase 3(ii).

**23** UB-785 2365 ± 70 BP $\delta^{13}C$ –24.2 ± 0.2 ‰
Oak charcoal. Post in slot J. Phase 3(ii).

**24** UB-786 2370 ± 70 BP $\delta^{13}C$ –24.1 ± 0.2 ‰
Ash and alder charcoal. From fill of slot Z. Phase 3(ii).

**25** UB-787 2465 ± 160 BP $\delta^{13}C$ –23.9 ± 0.2 ‰
Ash charcoal. From slot X. Phase 3(ii).

**26** UB-788 2260 ± 45 BP $\delta^{13}C$ –23.2 ± 0.2 ‰
Ash charcoal. From slot Y. Phase 3(ii).

**27** UB-790 2105 ± 70 BP $\delta^{13}C$ –23.7 ± 0.2 ‰
Ash and alder charcoal. From upper filling of slot Z′. Phase 3(ii).

**28** UB-970 2315 ± 45 BP $\delta^{13}C$ (–25 ± 1 ‰)
Alder charcoal. From feature 126. Phase 3?

**29** UB-971 2085 ± 75 BP δ13C –25.0 ± 0.2 ‰
Oak charcoal. From dark fill of peripheral pit 16. Phase 3(i).

**30** UB-972 2170 ± 70 BP $\delta^{13}C$ (–25 ± 1 ‰)
Oak charcoal. From post-pit of mrts. Phase 4.

**31** UB-973 1785 ± 230 BP $\delta^{13}C$ –24.6 ± 0.2 ‰
Alder charcoal. Burning directly under red daub over slot C1. Phase 3(ii).

**32** UB-974 3140 ± 45 BP $\delta^{13}C$ –24.5 ± 0.2 ‰
Oak and alder charcoal. 'Lining' to clay core in peripheral pit 15. Phase 3(i).

**33** UB-976 1785 ± 45 BP $\delta^{13}C$ (–25 ± 1 ‰)
Oak and alder charcoal. From slot A2. Phase 3(ii).

**34** UB-977 2245 ± 70 BP $\delta^{13}C$ –24.6 ± 0.2 ‰
Ash charcoal. From slot B3. Phase 3(ii).

**35a/b** UB-978 2045 ± 35 BP $\delta^{13}C$ –24.7 ± 0.2 ‰
Alder and ash charcoal (including ash of more than 50 years age). From slot C3. Phase 3(ii). Mean of two dates: 2076 ± 45, 2015 ± 45. These dates will be used separately.

**36** UB-979 2615 ± 75 BP $\delta^{13}C$ –23.7 ± 0.2 ‰
Hazel and alder charcoal. From the 'base' of the ditch. Phase 3(i).

**37** UB-982 2550 ± 60 BP $\delta^{13}C$ –23.9 ± 0.2 ‰
Carbonized stake of oak. From wall-slot E3. Phase 3(iii). This stake, dendro-sample Q2157, had 66 rings and no sapwood. A dendrochronological date could not be obtained.

**38** Oxa-3321 2150 ± 70 BP $\delta^{13}C$ –20.3 ‰
Collagen from Barbary ape skull. From fill of slot C2. Phase 3(ii).

**39** UB-3307 1643 ± 26 BP $\delta^{13}C$ –24.9 ± 0.2 ‰
error multiplier 1.6
*Site A.* Collagen from animal bones. 'Occupation soil' some way up ditch fill.

**40** UB-3308 1517 ± 29 $\delta^{13}C$ –25.6 ± 0.2‰
error multiplier 1.6
*Site A.* Collagen from animal bones. 'Occupation soil' some way up ditch fill.

## Date-List 2: Radiocarbon Dates — Primary Data Summary in Laboratory Number Order

| no | lab no | date BP | sample type | context |
|---|---|---|---|---|
| 1 | UB-186 | 2415 ± 50‡ | charcoal (oak) | B mrts destruction |
| 2 | UB-187 | 2345 ± 55‡ | (charcoal) | B early 3(ii) over 3(i) ditch |
| 3 | UB-188 | 2630 ± 55‡ | (charcoal) | B 3(i) ditch, primary fill |
| 4 | UB-202 | 2215 ± 55‡ | charcoal (small branches, inc. hazel)* | B mrts destruction |
| 5 | UB-203 | 2360 ± 55‡ | charcoal (inc. ash)* | B slot C3 |
| 6 | UB-467 | 2100 ± 65‡ | burnt branch | B mrts destruction |
| 7 | UB-468 | 2295 ± 70 | burnt straw | B mrts destruction |
| 8 | UB-469 | 2150 ± 70 | twigs [and wood]* | B mrts construction, central-post packing |
| 9 | UB-470 | 2130 ± 70‡ | 13-year-old branch (birch) | B mrts construction, central-post packing |
| 10 | UB-752 | 2175 ± 45 | charcoal (alder [twigs?])* | A phase 1, outer slot |
| 11 | UB-770 | 2240 ± 50 | burnt plank (oak) | A phase 1, inner slot |
| 12a | UB-771 | 2440 ± 55 | burnt timber | B mrts construction, central-post packing |
| 12b | UB-771 | 2150 ± 80 | as 12a | as 12a |
| 13 | UB-772 | 2175 ± 45 | timber, *c.* 100 years from bark | B mrts construction, central post |
| 14 | UB-773 | 2020 ± 35 | burnt straw | B mrts destruction |
| 15a | UB-774 | 2195 ± 80 | burnt timber (alder) | B mrts destruction |
| 15b | UB-774 | 2125 ± 85 | as 15a | as 15a |
| 16 | UB-775 | 2395 ± 235 | burnt timber (ash) | B mrts destruction |
| 17 | UB-778 | 2220 ± 70 | burnt stake (ash) | B wall in slot N |
| 18 | UB-780 | 2240 ± 70 | charcoal (hazel) | B contemporary with slot G |
| 19 | UB-781 | 2505 ± 50 | charcoal (hazel) | B slot G |
| 20 | UB-782 | 2185 ± 55 | charcoal (ash, hazel) | B slot W |
| 21 | UB-783 | 2320 ± 70 | burnt plank (ash), bone | B wall in slot V |
| 22 | UB-784 | 2110 ± 45 | burnt plank (alder) | B wall in slot R |
| 23 | UB-785 | 2365 ± 70 | charcoal (post, oak) | B wall in slot J |
| 24 | UB-786 | 2370 ± 70 | charcoal (ash, alder) | B slot Z |
| 25 | UB-787 | 2465 ± 160 | charcoal (ash) | B slot X |
| 26 | UB-788 | 2260 ± 45 | charcoal (ash) | B slot Y |
| 27 | UB-790 | 2105 ± 70 | charcoal (ash, alder) | B slot Z′ |
| 28 | UB-970 | 2315 ± 50‡ | charcoal (alder) | B mrts construction ? |
| 29 | UB-971 | 2085 ± 75 | charcoal (oak) | B 3(i) peripheral pit, dark fill |
| 30 | UB-972 | 2170 ± 75‡ | charcoal (oak) | B mrts construction |
| 31 | UB-973 | 1785 ± 230 | charcoal ([alder]) | B wall? in slot C1 |
| 32 | UB-974 | 3140 ± 90 | charcoal (oak, alder) | B 3(i) peripheral pit, lining clay core |
| 33 | UB-976 | 1785 ± 50‡ | charcoal (oak, alder) | B slot A2 |
| 34 | UB-977 | 2245 ± 70 | charcoal (ash) | B wall? in slot B3 |
| 35a | UB-978 | 2075 ± 45 | charcoal (alder, ash) | B wall? in slot C3 |
| 35b | UB-978 | 2015 ± 45 | as 35a | as 35a |
| 36 | UB-979 | 2615 ± 75 | charcoal (hazel, alder) | B 3(i) ditch, primary fill |
| 37 | UB-982 | 2550 ± 60 | burnt stake (oak, 70++ years) | B wall in slot E3 |
| 38 | Oxa-3321 | 2150 ± 70 | skull of Barbary ape | B in slot C2 |
| 39 | UB-3307 | 1645 ± 25 | animal bones | A occupation material in ditch |
| 40 | UB-3308 | 1515 ± 30 | animal bones | A occupation material in ditch |

## Date-List 3: Calibrated Radiocarbon Dates by Phase and Feature Type

| no | context | sd* | range 1 sample-date | a-l | status | range 2 context-date |
|---|---|---|---|---|---|---|
| **Site A, wall-slots of phase 1** | | | | | | |
| **10** | outer | 70 | 390 BC – 60 BC | 0 | c/r | 390 BC – 60 BC > |
| **11** | inner (wall plank) | 80 | 440 BC – 120 BC | 250 | c | 370 BC – AD 60 |
| **Site A, layer of occupation material in ditch fill** | | | | | | |
| **39** | | 35 | AD 340 – AD 440 | 0 | c | AD 340 – AD 440 |
| **40** | | 35 | AD 440 – AD 620 | 0 | c | AD 440 – AD 620 |
| **Site B, phase 3(i), ditch** | | | | | | |
| **3** | primary fill | 85 | 950 BC – 550 BC | 250 | c/r | 880 BC – 370 BC > |
| **36** | primary fill | 115 | 1010 BC – 440 BC | 80 | c/r | 980 BC – 390 BC > |
| **Site B, phase 3(i), peripheral pits** | | | | | | |
| **32** | lining clay core | 135 | 1740 BC – 1030 BC | 200 | c/r | 1660 BC – 910 BC > |
| **29** | dark fill | 115 | 390 BC – AD 140 | 250 | c/r | 310 BC – AD 310 > |
| **Site B, phase 3(ii), 'early'** | | | | | | |
| **2** | over 3(i) ditch | 85 | 770 BC – 220 BC | 250 | c | 700 BC – 40 BC |
| **Site B, phase 3(ii), southern ring-slots** | | | | | | |
| **33** | A2 fill | 80 | AD 50 – AD 410 | 200 | r | AD 110 – AD 550 |
| **34** | B3 (wall?) | 105 | 730 BC – 50 BC | 150 | c/r | 670 BC – AD 40 > |
| **31** | C1 (wall?) | 350 | 730 BC – AD 940 | 100 | c/r | 680 BC – AD 990 |
| **38** | C2 fill | 75 | 390 BC – 20 BC | 0 | c | 390 BC – 20 BC |
| **5** | C3 (wall?) | 85 | 780 BC – 220 BC | 200 | c/r | 720 BC – 80 BC > |
| **35a** | C3 (wall?) | 70 | 340 BC – AD 50 | 120 | c/r | 300 BC – AD 130 > |
| **35b** | C3 (wall?) | 70 | 190 BC – AD 110 | 120 | c/r | 150 BC – AD 190 > |
| **Site B, phase 3(ii), northern ring-slots** | | | | | | |
| **20** | W | 85 | 410 BC – 30 BC | 100 | r | 370 BC – AD 30 > |
| **21** | V (wall-plank) | 105 | 780 BC – 150 BC | 150 | c | 720 BC – 60 BC |
| **17** | N (wall-stake) | 105 | 510 BC – 20 BC | 150 | c | 450 BC – AD 70 |
| **22** | R (wall-plank) | 70 | 360 BC – AD 20 | 100 | c | 320 BC – AD 80 |
| **23** | J (wall-post) | 105 | 800 BC – 190 BC | 250 | c | 720 BC – 20 BC |
| **18** | 'contemporary with G′ | 105 | 540 BC – 50 BC | 50 | c | 510 BC – 30 BC |
| **19** | G | 80 | 830 BC – 410 BC | 50 | c/r | 810 BC – 380 BC > |
| **Site B, phase 3(ii), 'avenue' slots** | | | | | | |
| **24** | Z | 105 | 800 BC – 200 BC | 120 | r | 750 BC – 130 BC > |
| **25** | X | 240 | 1160 BC – AD 1 | 150 | r | 1090 BC – AD 80 > |
| **26** | Y | 70 | 450 BC – 150 BC | 150 | r | 400 BC – 50 BC > |
| **27** | Z′ | 105 | 390 BC – AD 100 | 120 | r | 340 BC – AD 170 > |
| **Site B, phase 3(iii), 'house' slots** | | | | | | |
| **37** | E3 (wall-stake) | 95 | 880 BC – 420 BC | 250 | c | 800 BC – 250 BC |
| **Site B, phase 4, mrts 'construction'** | | | | | | |
| **28** | pit? | 80 | 740 BC – 200 BC | 100 | c/r | 700 BC – 140 BC > |
| **12a** | post-packing | 85 | 810 BC – 370 BC | 250 | c | 740 BC – 190 BC |
| **12b** | post-packing | 120 | 440 BC – AD 90 | 250 | c | 370 BC – AD 270 |
| **13** | central post | 70 | 390 BC – 60 BC | +100 | c | 290 BC – AD 40 |
| **8** | post-packing | 105 | 390 BC – AD 50 | 100 | c | 350 BC – AD 110 |
| **9** | post-packing | 105 | 400 BC – AD 80 | +5 | c | 400 BC – AD 80 |
| **30** | post-pit fill ? | 115 | 440 BC – AD 40 | 250 | r | 350 BC – AD 200 > |

| no | context | sd* | range 1 sample-date | a-l | status | range 2 context-date |
|---|---|---|---|---|---|---|
| **Site B, phase 4, mrts 'destruction'** | | | | | | |
| **1** | | 80 | 790 BC – 370 BC | 250 | c | 720 BC – 190 BC |
| **7** | | 105 | 770 BC – 110 BC | 0 | c | 770 BC – 110 BC |
| **4** | | 85 | 430 BC – 80 BC | 20 | c | 420 BC – 70 BC |
| **14** | | 55 | 160 BC – AD 90 | 0 | c | 160 BC – AD 90 |
| **15a** | | 120 | 510 BC – AD 30 | 100 | c | 470 BC – AD 90 |
| **15b** | | 130 | 430 BC – AD 120 | 100 | c | 390 BC – AD 180 |
| **6** | | 100 | 390 BC – AD 90 | 50 | c | 320 BC – AD 120 |
| **16** | | 350 | 1390 BC – AD 340 | 150 | c | 1320 BC – AD 460 |

**Key to Abbreviations in Date-Lists**

| | |
|---|---|
| lab no | Laboratory number (UB = Radiocarbon Dating Laboratory of Queen's University, Belfast; Oxa = Oxford University Accelerator Dating Facility) |
| date BP | The conventional radiocarbon date as supplied by the laboratory, rounded to the nearest five years. |
| ‡ | The standard deviation has been adjusted for isotopic fractionation by estimation, after release by the laboratory. |
| *Sample type* | |
| ( ) | Information not in 'published' source (see introduction to Date-list 1). |
| * | Sample not described as single piece or single type, but may be mixed with material of a potentially greater age-lapse. |
| *Context* | |
| A | Site A. |
| B | Site B. |
| mrts | Multi-ring timber structure. |
| construction | Described by excavator as 'construction' context of mrts, for example timber of the building itself. |
| destruction | Described by excavator as 'destruction' context of mrts. |
| sd* | Standard deviation adjusted for all necessary errors as explained in text. This forms the basis of the range calculations. |
| range 1 | Estimate of sample-date (that is, calibrated 95% range, not adjusted for old-wood effect). |
| a-l | Estimate of age-lapse (that for bone is insignificant). |
| +N | Actual age correction (that is, known old-wood value). |
| status | Estimate of relationship of sample to context. |
| c | Contemporary. |
| r | Probably residual (that is, older than context). |
| c/r | Possibly residual. |
| range 2 | Estimate of context-date (that is, calibrated 95% range, corrected for old-wood effect and indicating possible residuality by the use of '>', which means 'or later'). |

## Notes

1 Most of the dates (**1** to **37**) were produced by the Radiocarbon-Dating Unit of Queen's University, Belfast, between 1968 and 1975. Only five have been published by the laboratory (Smith *et al* 1970). All these samples were converted to methane, after appropriate pre-treatment. Sample **38** was dated by accelerator-mass-spectrometry (AMS) at Oxford University. Samples **39** and **40** were dated by the Queen's University laboratory after conversion to benzene. All dates are listed in Date-lists 1 and 2. As will be seen, three samples were measured twice, and for each pair we use each measurement as if it were an assessment of a different sample, having no grounds for assuming that in each case the sub-samples were of an identical nature.

2 Yet, as Fig 73 shows clearly, even the conventional dates as originally published showed no chronological trend consistent with the stratigraphy but appeared, within a wide bracket, to be quite random (see Lynn 1986b, 16–17).

3 An 'absolute date' is a date in 'real', 'sidereal', 'solar' or 'calendar' years.

4 The first published suggestion that this traditional chronology was wrong will be found in Warner 1994b, 66.

5 In earlier publications the radiocarbon date is often given as BC/AD (or bc/ad) as if it represented an absolute date. As we will see in this text, it is clear that 'radiocarbon years BP' are not absolute years, and the convention now is to use BP as a shorthand for 'radiocarbon age' in 'radiocarbon years'.

6 Even so we must bear in mind that at 95% probability there remains a 1 in 20 chance that the true value of the measurement lies outside that bracket. There is a very much greater probability (over 99%) that the true value lies within a plus-or-minus three standard deviation bracket but such a bracket, though it increases the probability that the estimate reflects the real date, seriously weakens its archaeological usefulness. On the other hand, the single standard deviation bracket widely used by many archaeologists in interpreting dates is more precise but guarantees no better a probability than two in three of containing the true value. Ninety-five per cent is a fair compromise between accuracy and precision and has long been used by statisticians as the minimum bracket of probability, or confidence, with which it is wise to deal, and increasingly also by archaeologists (see Bowman 1990, 39, for the important distinction between precision and accuracy).

7 G Pearson, director of the Queen's University laboratory when dates **1** to **37** were produced, has suggested that an error multiplier of 1.25 is sufficient to allow for these unknown errors in the case of the Navan dates. However, prompted by a suggestion of M Baillie that Belfast dates with a quoted standard error of less than 70 years were unrealistic (Baillie and Pilcher 1983, 56), Baillie, G McCormac (the present director of the laboratory) and I have investigated a group of known-date samples for the first millennium BC produced in Belfast on the same equipment, by the same procedures and at the same time as the Navan dates. It was clear that the sample dates for Navan should either be given a minimum standard deviation of 90 years or be subjected to an error multiplier of 1.5. We have used the second alternative on the advice of G McCormac. It should be remembered that enlarging the error term decreases the precision of the date but increases the probability that it actually reflects the true value (see note 6). Dates **38**–**40** inclusive have quoted standard deviations that already include potential laboratory errors (error multiplier = 1.6 for **39** and 1.4 for **40**) and we are advised by the laboratories that no further adjustment is necessary.

8 Some sophisticated procedures and programmes allow a calibrated date to be obtained which contains probabilistic structure. I do not regard these procedures as either safe or useful, though with time an acceptable procedure will no doubt emerge.

9 For this report I have used the limit-intercept method in which the M ± 2 sd* limits of the conventional date are calibrated, the outermost intercepts being used. These are outwardly rounded to the nearest ten years. The results, produced by my own computer programme and based on the calibration curves of Stuiver and Pearson (1986) and Pearson and Stuiver (1986), are indistinguishable from those obtained on the same set of dates using the CALIB program of Stuiver and Reimer (1986).

10 I have avoided the popular, but rather clumsy use of Cal BC and Cal AD to indicate this.

11 In discussing the Danebury dates Cunliffe and Orton (1984, 190) appear to dismiss the old-wood effect on the basis of paired (short-life and long-life) samples from the site failing to show a significant difference. In fact their table 18 is erroneous and the bone samples are indeed inconsistent with other evidence. They recognize (Cunliffe and Orton 1984, 193), but make no allowance for the fact, that a bias is present, the long-life (charcoal) samples being on average about 200 years older than the short-life (grain) samples, exactly as I would predict to be a general consequence of the old-wood effect. The old-wood effect is apparent in many published reports, though not always recognized. The clearest recent demonstration of its ubiquity and potential size is by Anderson (1991).

12 It must be stressed that use of the age-lapse (the *maximum* likely organic age of the sample) in the calculation to allow for the potential old-wood effect does not assume that the sample is that maximum age. It assumes an *equal probability* that the actual organic age lies somewhere between zero and the age-lapse value. If whole-trees were *always* used completely and burned with equal thoroughness we might expect to be able to predict a 'shape' to the age-lapse curve, and assign probabilities to wood being *much* too old or *slightly* too old. Unfortunately, we do not yet have evidence for such an assumption.

13 Millett and James (1983, 198) have recognized the inherent problem of the old-wood effect and attempted a different solution. They have used an estimate of the actual organic age of the sample based on the ring-widths of the sample and on a hypothesis that there is a correlation between ring-width and organic age. Despite the fact that their organic age estimates are very much in line with my predictions their hypothesis has, according to M Baillie and J Pilcher (personal communication), no basis in fact and the method cannot be recommended.

14 These values have been arrived at after discussions with J Pilcher and M Baillie of Queen's University, Belfast, and P Hackney of the Ulster Museum. In previous papers on this subject (including Warner 1990) I suggested 200 years as the age-lapse for oak. After discussions with M

Baillie I increased it to 250 years although, as we see in the analysis of the multi-ring timber structure dates, this might still be too low.

15 By J Pilcher, J Hillam and R Larmour.

16 In the laboratory register the identifications of sample type are given (when at all) very briefly. A typescript list of dates produced for publication (but not actually published) in the journal *Radiocarbon* repeats most of these identifications, but not all of them. In a few cases there is added or different information. In Date-lists 1 and 2 I have distinguished between the sources.

17 Besides its simplicity the value of this analytical method is that it can be applied without knowledge of the detailed probabilistic nature of the date within its 95% limits, a complex matter resulting from the variability of the atmospheric radiocarbon proportion and of the old-wood effect. The complicated interpretative methods of Cunliffe and Orton (1984) and Wilson and Ward (1981) cannot cope with these variations and unknowns, nor can they be applied where the old-wood effect is likely to exist. They cannot therefore be recommended. The statistical stratigraphic calibration method of Buck *et al* (1994) is likely to prove useful in some circumstances, but again it cannot cope with the old-wood effect. Although my analytical technique lacks statistical rigour it is robust and easy to use and to apply without statistical expertise. I have no doubt that the 'black box' analysis of radiocarbon dates will eventually become commonplace, but my procedure gives virtually the same results as Buck's complex procedure for the Runnymede and Skara Brae dates (Buck *et al* 1991).

18 The seven construction dates provide a T-value of 14 with 6 degrees of freedom (weighted mean for the group is 2215 ± 35 BP). The null-hypothesis NH(1) has less than a 5% level of probability and is rejected. The eight destruction dates give a T-value of 21 with 7 degrees of freedom (weighted mean 2175 ± 30 BP). NH(1) for this group has less than a 0.5% probability and is rejected. The fifteen combined dates give a T-value of 36 with 14 degrees of freedom (pooled mean 2200 ± 25 BP). This also requires rejection of NH(1) at the 0.5% level of probability. It should be noted that unadjusted sample dates would have caused rejection of NH(1) at an even lower level of probability.

19 In this modified test the three groups named in footnote 18 give T-values of 30, 30 and 60. In all cases the null-hypothesis NH(2) is rejected at less than 0.1% probability. It should also be pointed out that the pooled means are not acceptable, even at the 0.1% level of probability, as estimates of the known context date.

20 $se^2 = sd^{\star 2} + sc^2$ where $sd^\star$ is the adjusted standard deviation of the sample-date and sc=20 — the standard deviation of the reverse-calibrated radiocarbon date of the construction.

21 The standard error of the deviation (se) is obtained by $se^2 = sd^{\star 2} + sw^2 + sa^2$, where sw is the weighted standard error of the dates and sa is an estimate of the standard error of the age-lapse — (a–l)/4.

22 Against their own weighted mean (NH1) the dates give a T-value of 19, which has a greater than 5% probability and is not rejected. Against the known date of 2070 ± 20 BP the T-value is 25, which has a 4% probability, and need not be rejected.

23 For construction, T = 11, which has a probability of 10%. For destruction, T = 14, which has a probability of 5%.

24 The three groups in this analysis are: samples with age-lapse 200 years or greater, samples with age-lapse 100 years to less than 200 years, and samples with age-lapse less than 100 years or precisely known and corrected for. The weighted means of the three groups are 2315 ± 45, 2250 ± 55 and 2105 ± 30.

25 For the three groups, for NH(1) T = 10, 2 and 8 with probabilities of <5%, > 10% and >10%, and for NH(2) T = 39, 36 and 8 with probabilities of <<0.1%, <<0.1% and >10%.

26 For the conventional dates T=54, with 18 degrees of freedom. This has a probability of less than 0.1% and is rejected. For the age-lapse adjusted means T=38, which has a probability of 0.5% and should also be rejected. In this case we have no known date to compare these with, so NH(2) does not apply.

27 Extraordinarily, and quite obviously coincidentally, the weighted mean of the uncalibrated pit dates, 2530 ± 90, is statistically indistinguishable from that of the two ditch dates, 2625 ± 70!