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## **Towards a standardized discussion of priors in Bayesian analyses of $^{14}\text{C}$ dated archaeological periods: A study based on the dates from Gjøsund**

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## ABSTRACT

Frands Herschend 2016. Towards a standardized discussion of priors in Bayesian analyses of  $^{14}\text{C}$  dated archaeological periods: A study based on the dates from Gjøesund.

This article focuses on Swedish and Scandinavian contract archaeology and  $^{14}\text{C}$  dating. It is a follow-up of a case study by Diinhoff and Slinning (2013), who discuss the  $^{14}\text{C}$  dating of a house from the Early Iron Age at Gjøesund, Ålesund, Norway. Their discussion is methodical and well-focussed, but intuitive when it comes to analysing  $^{14}\text{C}$  dates as probability distributions. Taking the case study forward, the same house is dated again using the same  $^{14}\text{C}$  dates. In the present contribution, the discussion is meant to suggest a more standardized approach to the chronological analysis of  $^{14}\text{C}$  dates of periods, such as the lifetime of a house. Having presented a methodical procedure, Diinhoff and Slinning's case is updated following the suggested procedure. Finally, their  $^{14}\text{C}$  dates are introduced to Bayesian statistics using the BCal calibration tool, Beck *et al.* (1999).

**KEYWORDS:** Chronology; Methodology; Bayesian statistics; BCal calibration tool; Contract archaeology; Early Iron Age; West Norway; Gjøesund.

## Towards a standardized discussion of priors in Bayesian analyses of <sup>14</sup>C dated archaeological periods: A study based on the dates from Gjøssund

### Contract archaeology and <sup>14</sup>C dates

In contract archaeology, hundreds of <sup>14</sup>C samples are submitted to radiocarbon laboratories each year. For instance, the Tandem Laboratory in Uppsala processed between 1400 and 1600 archaeological <sup>14</sup>C samples in 2015<sup>2</sup>. Every year, archaeologists responsible for using and publishing the hundreds of dates returned to them chose to analyse the results cautiously, without pushing the dates too far. For example, the 71 <sup>14</sup>C dates from the Iron Age village Berget, which thrived mainly in the Roman Iron Age, stand out as a time cloud that structures the discussion of settlement, farms and houses in broad terms. A typical chronological structure may be labelled ‘Early Roman Iron Age’, ‘Late Roman Iron Age’, ‘Migration Period’ and ‘Vendel Period’, see Göthberg *et al.* (2014:251–268). Since the dates are so many, they give a ball-park idea of the main settlement period collected in tables and illustrated as a series of calendar-year probability distributions, most often sorted by the centroid <sup>14</sup>C dates in an informative OxCal diagram (Göthberg *et al.*, 2014:225–233). Today, this approach is standard and adhered to, for instance, by Diinhoff and Slinning (2013:Fig. 5). When it comes to finer chronological points, and as discussed by Diinhoff and Slinning (2013:66), one or two samples dating a context, such as the remains of a house, may at best give a very wide chronological anchoring. That is why most archaeologists, e.g. Göthberg *et al.*, prefer to discuss the general structure of the village and its farms rather than individual houses (2014:251–268). For perfectly good reasons, archaeologists change their priorities from dating the houses to dating broader archaeological contexts, e.g. Göthberg *et al.* (2014:23). Nevertheless, heritage authorities, such as *Slott- og kulturstyrelsen*, advise archaeologists specifically to date houses, that is the buildings, in order to create an overview: ‘One ought to make at least two and preferably three <sup>14</sup>C dates per house’ — *Der bør laves mindst to og helst tre C14-dateringer pr. hus*, Olsen (2115:Fokuspunkter). Strictly adhering to this advice will limit context-based research design significantly.

From a scientific point of view, the rapidly growing number of dates never used outside excavation reports is unsatisfactory. First, information about

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2 Engineer Elisabet Pettersson at the Uppsala Tandem Laboratory has kindly informed me of the number of archaeological samples. Needless to say, they are a fraction of the total number of samples dated at the Laboratory

the past tends to be confined to specific report discussions although the information is probably general. Second, if the chronological information does reach outside the primary publications, its chronological cloudiness is often enhanced owing to the cautiousness to which archaeologists must subscribe.

The conclusion that coastal settlements in Iron Age Scania disappear between the 4th and the 8th century is a case in point. This abandonment is an important and often acknowledged fact, but also a wide-framed  $^{14}\text{C}$  supported interpretation, see e.g. Brink and Hammarstrand (2013:186ff. with ref.). Nevertheless, it is conceivable that analysing all end dates on settlements that disappear from the coastal area c. 300 CE could enhance our knowledge of the abandonment.

## A methodical procedure

An important theoretical problem using  $^{14}\text{C}$  date concerns the way in which we combine two kinds of time. How can we combine universal time expressed, for instance, in the half-life of the radioactive isotope, with contextual time, as expressed by the archaeological remains? The calibration curve demonstrates that the former, measuring universal time, is not without its problems although they can be described (c.f. Steel 2000). The latter, contextual time, on the other hand, is a complex matter of interpretation, involving several parameters. Their characters are difficult to describe and it is problematic to bypass the circumstantial discussion needed to understand the parameters. Although problems related to  $^{14}\text{C}$  samples are many and complex, both during excavation and the ensuing process that results in a report, there are four easily defined problem areas to consider.

- (1) What is the relation between a  $^{14}\text{C}$  sample and its archaeological context?
- (2) What does humanly-produced archaeological  $^{14}\text{C}$  samples actually date?
- (3) How is universal time depicted by archaeological  $^{14}\text{C}$  samples?
- (4) How should the probability distribution of  $^{14}\text{C}$  dates be treated?

During the past three or four decades, these questions have been addressed in different ways as they have presented themselves, not least owing to the development of contract archaeology, e.g. Kyhlberg (1982); Herschend (1994); Kyhlberg & Strucke (1999); Norr (2009); Diinhoff and Slinning (2013).

In 2001, Bäck & Strucke (2003) exemplified and discussed Bayesian calibration of  $^{14}\text{C}$  tests. They focussed on the problems concerning the calibration curve as well as relative and absolute chronological *a priori* grouping of tests, before they applied OxCal to their specific case, the dating of the Årby Kvarn. So far, during the past 15 years, in which more than 10,000 new  $^{14}\text{C}$  tests have become available to Swedish contract archaeology, their pioneering article has not been followed up.

Within Swedish contract archaeology, the growing importance of strip, map and sample methods at badly preserved sites have resulted in the need to construct chronology by means of materials suitable for  $^{14}\text{C}$  dating.

Consequently, questions about the ability of these proxy variables to date a cultural context have arisen. Norr (2009) and Diinhoff and Slinning (2013) mirror this new archaeological situation.

While the contextual problems are complex, problems concerning the reliability of the physical methods are negligible, as pointed out by Scott *et al.* (2010). There may still be the odd laboratory anomaly to discuss, see e.g. Vicente *et al.* (2015) and Meadows *et al.* (2015), but the sheer number of AMS dates and their present standard deviation around 30  $^{14}\text{C}$  years have made archaeologists more able to intuitively handle the effects of own age and outliers. Whether caused by history or laboratories, a few deviant dates among 50 or 70 seemingly correct ones are not a great problem. Many dates on a small settlement area with several building remains may simply provide archaeologists with an overview. The excavations at Huseby in Värend, with 39 dates among 24 house remains on a 7500m<sup>2</sup> area, demonstrate the success of the large indiscriminate set of tests (Söderberg and Nylén 2009:103–123). The need to create a chronological overview is also shown in the number of  $^{14}\text{C}$  dates per excavated square metre. For instance, in five small excavations conducted by *Societas Archaeologica Upsaliensis* during recent years, 9348 m<sup>2</sup> resulted in 37  $^{14}\text{C}$  dates or 1 per 250m<sup>2</sup> (c.f. Eklund 2008; Lindkvist 2012; Engström 2012; Hulth 2014; Hulth 2015). In four larger excavations, 130,550m<sup>2</sup> resulted in 201  $^{14}\text{C}$  dates or 1 per 650m<sup>2</sup> (see Onsten-Molander and Wikborg 2006A and 2006B; Korpås and Wikborg 2012; Sundkvist and Eklund 2014). In small strip, map and sample settlement excavations, contextual overview is more difficult to establish and thus archaeologists tend to rely more on  $^{14}\text{C}$  tests.

Each of the four problem areas that structure the methodical procedure can be dealt with in general and by means of three themes. Some of these may be treated in passing, others are more complex, and some must interact with each other. The procedure depends on the order of the themes, and as soon as one of them cannot be satisfyingly discussed, the procedure stops, and can only be restarted if looped back to an earlier problem area. Ultimately, however, only the more or less lax scientific conscience of the archaeologist can define what a satisfying methodological discussion is. That ‘scientific consciousness’ is a genuinely vague concept was demonstrated by the source critical discussions in Swedish archaeology around 1970, see for instance contributions to *Tor*, vol. 12 (1969–70).

The procedure (see Tab. 01) links an archaeological and contextual perspective to a situation in which it becomes reasonable to ask some more specific chronological questions that may benefit from a Bayesian analysis. The procedure can be illustrated in a chart (see fig. 1). As a model, the chart emphasizes a discussion and process that builds up a base of prior knowledge. In turn, prior knowledge is necessary for the Bayesian calculation of posterior probabilities, while posterior probability is the analytical result of the process.

The discussion that drives the procedure has a typical beginning centring on description and the archaeological context. Based on the first part, the discussion in the two following central parts is more involved in interpreting

Table. 1. Overview of the methodical procedure.

<b>AREA:</b>	<b>I) WHAT IS THE RELATION BETWEEN A <math>^{14}\text{C}</math>-SAMPLE AND ITS ARCHAEOLOGICAL CONTEXT?</b>
<b>THEMES:</b>	
I:I	The site as a functioning environment
I:II	The prehistoric reality as decaying material phenomena
I:III	The archaeological context as duration
<b>AREA:</b>	<b>II) WHAT DOES A HUMANLY-PRODUCED ARCHAEOLOGICAL <math>^{14}\text{C}</math>-SAMPLE ACTUALLY DATE?</b>
<b>THEMES:</b>	
II:I	The own age of the sample
II:II	The varying number of $^{14}\text{C}$ -sample traps
II:III	The interpretation and relation of sub contexts containing $^{14}\text{C}$ -samples
<b>AREA:</b>	<b>III) HOW IS UNIVERSAL TIME DEPICTED BY AN ARCHAEOLOGICAL <math>^{14}\text{C}</math>-SAMPLE?</b>
<b>THEMES:</b>	
III:I	Sample production rate
III:II	Relative number of effective $^{14}\text{C}$ -sample traps
III:III	Sample preservation
<b>AREA:</b>	<b>IV) HOW SHOULD AN ARCHAEOLOGICAL <math>^{14}\text{C}</math>-SAMPLE PROBABILITY DISTRIBUTION BE TREATED?</b>
<b>THEMES:</b>	
IV:I	Scientific parameters
IV:II	Overview of probability distributions
IV:III	Bayesian-aided chronology

Table 1.

[http://files.webb.uu.se/uploader/92/Table\\_1.jpg](http://files.webb.uu.se/uploader/92/Table_1.jpg)

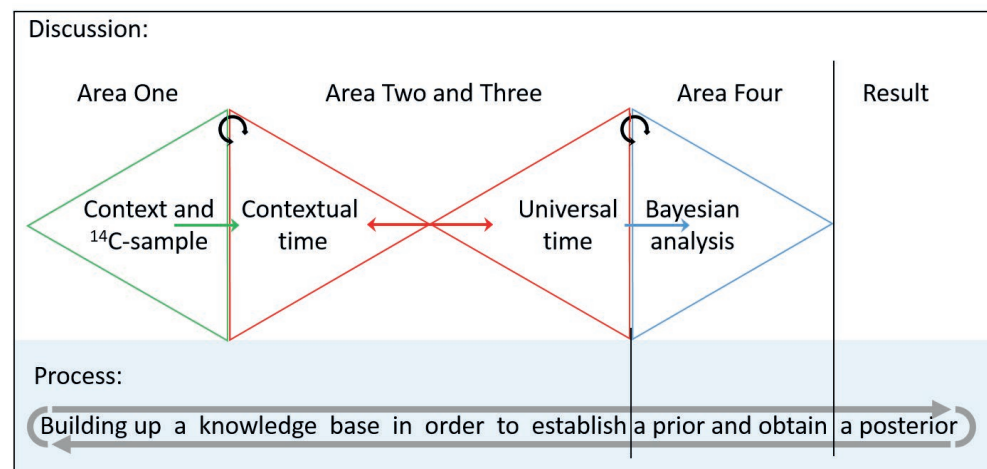


Fig. 1. The methodical procedure as a chart. There are two interrelated levels in the procedure – Discussion and Process. The process can be described as a sentence: “The process is a matter of: Building up a knowledge ...”. The discussion aims at creating a chain of discursive areas.

These interrelated levels illustrate a basic theoretical problem: How can a series of areas be chained in such a way that they constitute a process. The points in Table 1 are suggested as a practical way of achieving this. Nevertheless, there is no theoretical answer to the problem inasmuch as we may always discuss two fundamental issues, the first governing the other, as pointed out by e.g. Bronk Ramsey (2000:199). (1) What prior should be used for groups of dated samples? (2) What the results of the Bayesian analysis actually mean? Although they are interrelated, the levels are distinct.

[http://files.webb.uu.se/uploader/92/Fig\\_1.jpg](http://files.webb.uu.se/uploader/92/Fig_1.jpg)

the relation between context and time as a period. This discussion on chronology, which may loop back to the first part of the model for renewed discussion, results in prior facts. These priors are fed into the Bayesian analysis, which returns a posterior chronological probability. Evaluating this result, one may loop back to the central part of the model to adjust or develop the *a priori* understanding of the archaeological chronology before redoing the Bayesian analysis.

In principle, the first part of the discussion provides a necessary background, which is developed in the interactive central part. In turn, this part provides a platform for the final analytical part of the process. The procedure aims at defining a set of  $^{14}\text{C}$  samples and their relation to context and time.

Building the process is part of a never-ending endeavour that begins during excavation planning, develops during the excavation and reaches its first Bayesian dates during the research process that results in the report. Running the procedure sketched in Table 1 on a published material, such as the Gjøsumd dates, is a way of preparing oneself for future excavations.

## A note on the Gjøsumd case

The present case study revives Diinhoff and Slinning's paper following the above procedure. Their point of departure is contract archaeology, especially when it uses strip, map and sample methods. Their focus is on the first, the second and the fourth methodical area. I will not discuss their options and choices, or their approach. In the present context of methodology and method, the important point is their discussion, which overshadows the study itself and draws attention to relevant future questions concerning the usefulness of  $^{14}\text{C}$  dates.

The hypothesis formulated and tested by Diinhoff and Slinning (2013:68ff.) is linked to an excavation carried out in 2007, and their article contributes to an ongoing discussion within contract archaeology. Their prime target group is researchers with a substantial contract-archaeological experience, who appear in the Norwegian debate and prominently figure as authors and editors, for instance in *Primitiva tider. Arkeologisk tidsskrift*. Vol 15, 2013 or *Viking. Norsk arkeologisk årbok*. Vol. 77, 2014 and 78, 2015 as well as in the publication edited by Diinhoff and Slinning in 2013.

## The relationship between the test material and the archaeological context

Analysing the archaeological context is a matter of an intra-site analysis paired with broad comparative analyses drawing on a wealth of different contexts. Ideally, these analyses interact with each other.

### THE SITE AS A FUNCTIONING ENVIRONMENT

The Gjøesund site is located just north of Ålesund between the town and its airport (see Fig. 2). The site sits on the southern tip of the island Vigra on the flat foreland by the northern shore of the sound. The Gjøesund house is coastal and situated on a multi-purpose site with a rural emphasis, at least in archaeological terms. There has been sporadic presence from the Bronze Age and onwards. The excavations demonstrated human presence until *Merovingertid*, i.e. late 6<sup>th</sup> to early 8<sup>th</sup> c. CE (Diinhoff and Slinning, 2013:68). The archaeological record suggests that the area was settled, cultivated and known or at least recognized as a place with qualities and visited during fifty generations, albeit not continuously. This is by no means atypical. Some sites with a more elevated topographical situation, such as Ringdal 13 in Vestfold may have had an even longer period of recognition as a place, see e.g. Gjerpe and Østmo (2008:132).

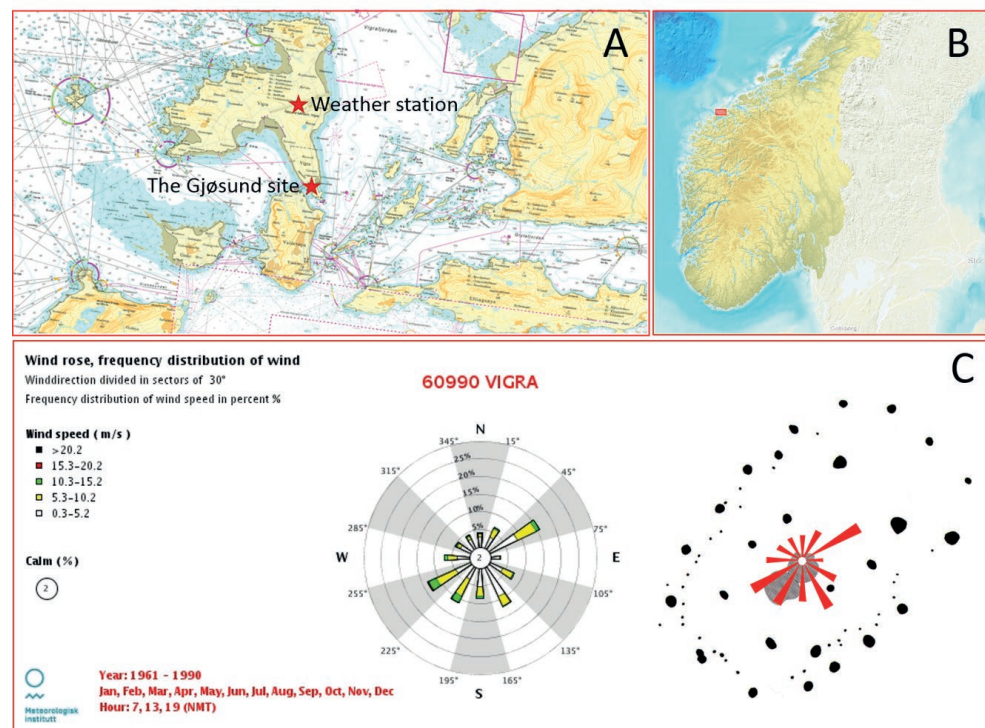


Fig. 2. The location and orientation of the Gjøesund house.  
[http://files.webb.uu.se/uploader/92/Fig\\_2.jpg](http://files.webb.uu.se/uploader/92/Fig_2.jpg)

## THE PREHISTORIC REALITY AS DECAYING MATERIAL PHENOMENA

Production and usage/decay constitutes the time aspect of material contexts. Archaeologists excavate their remains. On the Gjøssund site, Diinhoff and Slinning identified the remains of a small three-aisled house. It was an isolated context (Diinhoff and Slinning, 2013:70). With reference to the above theme, the orientation of the house seems to befit prevailing winds and sunshine – that is, the micro-environment. From an archaeological point of view, the house was relatively well-preserved (see fig. 2).

In a model way, the excavators decided that it was possible to test a chronological hypothesis within their budget. They theorized that Early Iron Age houses were short-lived and asked themselves whether <sup>14</sup>C dates could reveal the life length of this solitary house. In South Scandinavia and Northwest Europe, one-generation houses are common (Gerritsen 1999), not least in Jutland where they were model in the Pre Roman Iron Age (Herschend 2009:142–171).

The Gjøssund house is not without parallels. For instance, House 22 at Ringdal in Vestfold is similarly proportioned, albeit with remains of only three roof-supporting post pairs, i.e. trestles (fig. 3A & B, Gjerpe and Østmo 2008:114 & Fig. 3:3). This three-trestle pattern with an oblique central trestle can also be found in the Scania (Tesch 1993:172, Fig.12) and Jutland (Isler and Bech 2009:33) (see fig. 3C). In the Late Bronze and earliest Iron Age, houses with three trestles were not uncommon in Scania and Denmark (Tesch 1993:167–72, with ref.). In some Bronze Age contexts, such as the Viborg area in Jutland where oblique central trestles are uncommon, three-trestle houses may amount to c. 25% of the buildings. They are seldom superimposed by later buildings. In later Pre-Roman Iron Age settlements with overlapping houses they are uncommon, see e.g. settlement maps in Mikkelsen (2012).

In South Scandinavian Early-Iron-Age terms, Gjøssund is not typical, inasmuch as it has no central entrance room between dwelling and byre. Instead, Gjøssund looks like a small Bronze Age house with no obvious byre (see fig. 4 A–D). Thus, it is odd that it seems to have four trestles, not least while the two central ones do not define the central entrance room. If we agree with the above comparisons, then the entrances as observed by Diinhoff and Slinning should be in the eastern part of the house, and there should be no more than three roof-supporting trestles at a time. The askew central trestle is a partition between the dwelling part with the hearth as well as insulated walls and the economy/entrance part of the building. The central trestle is positioned awry in order to create a useful area along the northwest wall opposite the southern entrance. The broad mid-aisle created by the roof-supporting construction indicates a Bronze Age/Pre Roman Iron Age date, Diinhoff and Slinning (2013:68–9). The wall consists of freestanding wall posts carrying a rim combined with a light insulating wall as in Klegod in Jutland (see Aarup Jensen 1974) or Tofting in Northwest Germany (Bantelman 1955). Trestles support the side beams. The first and the last trestle also each support their

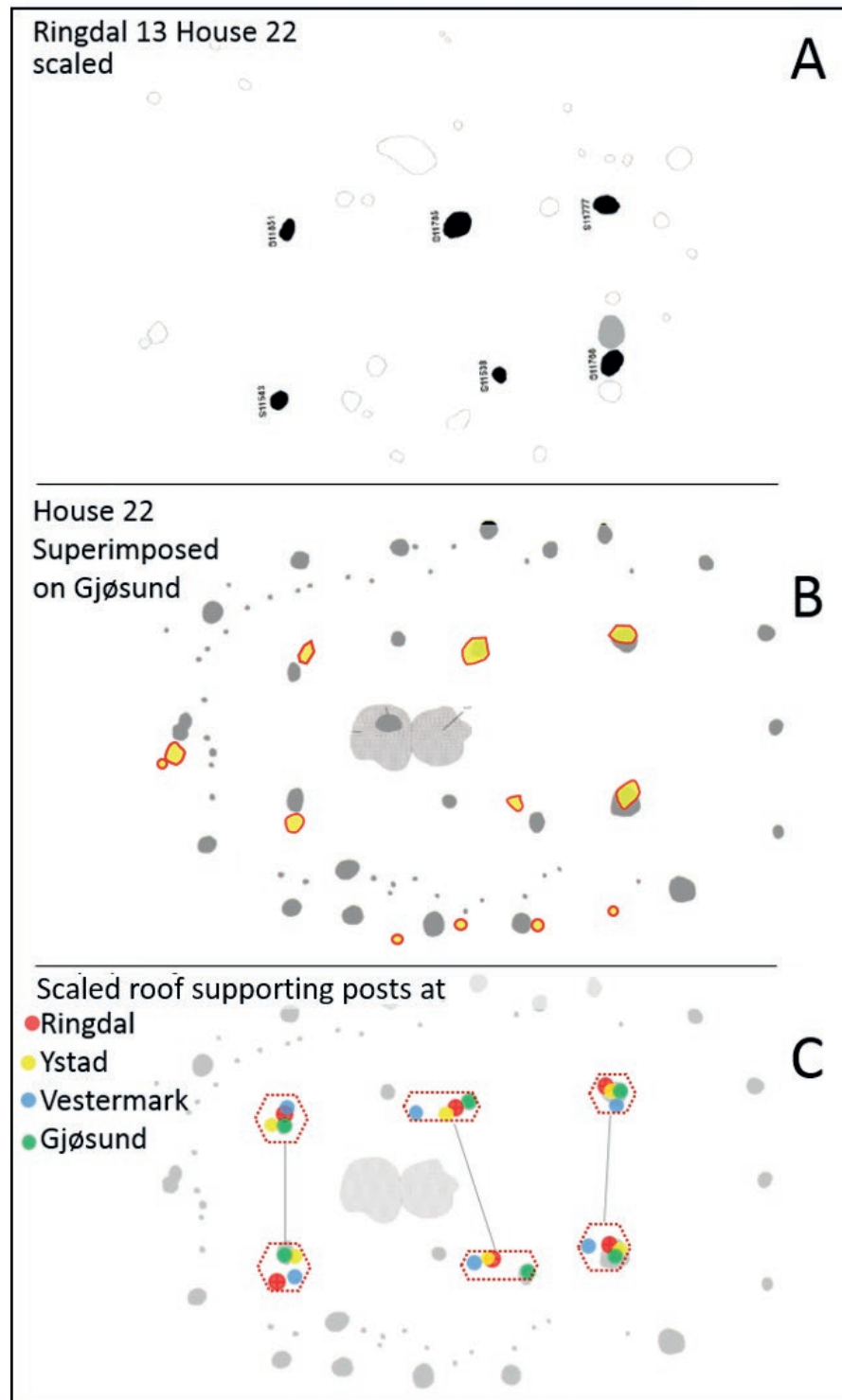


Fig. 3. Small Late Bronze or Early Iron Age houses with three trestles, the central one being oblique, can be scaled and superimposed upon each other as long as we focus on the roof-supporting posts. The wall constructions differ, although Ringdal and Gjøssund may have had similar walls. The position of the outer trestles is very similar, since they support the hips in the short ends, and because the plans are scaled. The central trestle, however, is fitted in where it is convenient, in all probability because it signifies a partition and not merely a roof support. For Ringdal, see Gjerpe and Østmo, 2008; for Ystad, see Tesch 1993; for Vestermark, see Isler and Bech 2009; for Gjøssund, see Diiinhoff and Slinning (2103).

[http://files.webb.uu.se/uploader/92/Fig\\_3.jpg](http://files.webb.uu.se/uploader/92/Fig_3.jpg)

hipped gable. The top ridge is supported either by a freestanding post or by dwarfs on the trestles. Rim, side beams, and top ridge support the rafters and the roof (Herschend 1989). The post settings in the short ends differ as in a Bronze Age/Pre Roman Iron Age house (cf. Becker 1972:15; Rindel 1997:104–5). This difference indicates that the short ends were constructed in two different ways. In the southwest, the hip was unbroken, while in the northeast, it was broken (see fig. 4B – D). Thus, the smoke probably left the house in the northeast. Gjosund is an uncommon type of house that was built during the Late Bronze and Early Iron Age in large parts of Scandinavia.

### THE ARCHAEOLOGICAL CONTEXT AS DURATION

The Gjosund house was never given a total make-over. Some patterns, nevertheless, suggest repairs – more in fact than those pointed out by Diinhoff and Slinning (2013). First of all, a post in the posthole-resembling features, (fig. 004A, feature 95c & H40), which trapped samples in the southwestern-most hearth, would seem to once having supported the top ridge and the unbroken southwestern hip. Since one cannot very well place a post in a

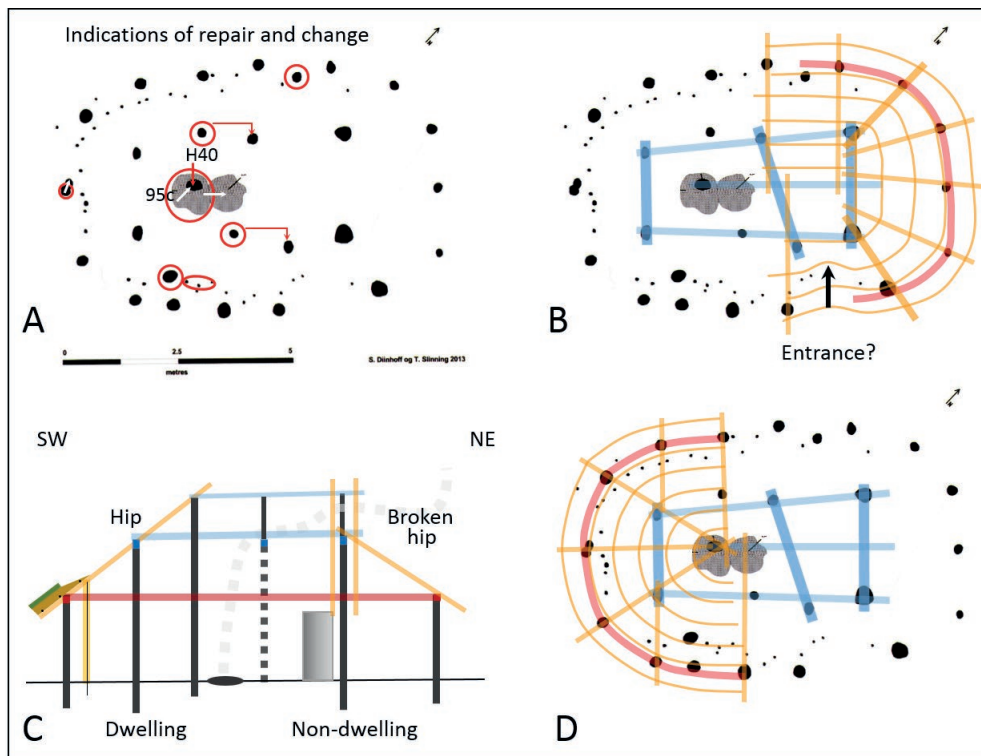


Fig. 4 A-D. Characteristics of the Gjosund house. A, indications signalling redesign and reparation. B-D, the principle of its roof construction. The supporting construction is Bronze Age/Pre Roman Iron Age and consists of free-standing wall posts carrying a rim as in Northwest Germany (Tofting Bantelman 1955). Trestles support the side beams. The first and the last trestle also support the hips in the gables. The top ridge is supported either by a free-standing post or by dwarfs on the trestles. Rim, side beams, gable trestles and top ridge support the rafters and the roof. The post settings in the short ends differ as in a Bronze Age/Pre Roman Iron Age house (Becker 1972:15, Fig.109; Rindel 1997:104-5, Hus B Xa).

[http://files.webb.uu.se/uploader/92/Fig\\_4.jpg](http://files.webb.uu.se/uploader/92/Fig_4.jpg)

hearth, 95c was probably the first posthole, situated just west of the hearth, to support the hip. Posthole H40 was dug into the old hearth when the new one was established just east of the original hearth, as suggested by plans and  $^{14}\text{C}$  dates. This would mean that the hearth and the central trestle were moved to the northeast during the lifetime of the house. The dwelling part was expanded without prolonging the building. It seems probable that the gable and the roof also were rebuilt, as indicated by the replaced central wall post in the southwestern short end (see fig. 4A). A number of irregular posts and some of the small rods that supported the insulating wattle-and-daub wall may also have been replaced. By and large there are traits that suggest several repairs and alterations. The house, therefore, is *not* a classical one-generation four-trestle South Scandinavian Pre Roman Iron Age house (cf. Herschend 2009:171–73). Its life time exceeds c. 30 years and from a South Scandinavian point of view, its architectural pattern with an unbroken as well as a broken hip is partly Bronze Age, partly Iron Age, e.g. typical Pre Roman Iron Age, Period 1 (see e.g. the house catalogue in Rindel 1997).

## What do the $^{14}\text{C}$ samples date?

There are some indications that when abandoned, Early Iron Age houses were preserved as flat rectangular monuments (Herschend 2009). There is even a case at Løvel in Jutland suggesting that such a monument was respected for hundreds of years (Beck and Kaldal Mikkelsen 2006:Fig. 8; Herschend 2009:156). Both House 22 at Ringdal (Gjerpe and Østmo 2008: Fig. 3:3) and the house at Gjørund were relative undisturbed by later activities and may thus have been visible as old house remains signifying the place as rooted in the past.

### THE OWN AGE OF THE SAMPLE

The  $^{14}\text{C}$  samples from Gjørund are small pieces of charred wood. Such a sample preserves a point or points in universal time when the cells' metabolism stopped. This simplicity stands against the human propensity to continuously use old organic material before consuming, forgetting or perhaps recycling it. These human norms create a need to establish the own age and the cultural age of the sample and to select samples with a low cultural age or own age. Since samples such as seeds or twigs (with a low own age) will seldom survive any longer cultural time, unless charred and trapped, they are optimal samples. Keeping the own age low was one of Diinhoff and Slinning's main concerns and they preferred birch when possible. Since the  $^{14}\text{C}$  samples must be protected, the growing complexity of a human settlement creates a growing number of  $^{14}\text{C}$  traps, which means that an archaeological site builds up a historical archive in the remains of a growing number of sub contexts which contain  $^{14}\text{C}$  samples. Diinhoff and Slinning chose the Gjørund house since it was a simple context limited in time and space – a place occupied only once by humans living in a house that stood during a limited period.

Own age and contextual age in archaeological terms is worth knowing and something archaeologists are keen to establish. The contamination risk, nevertheless, sees to it that control over contextual age is impossible to achieve. This is especially true of seeds and grains, i.e. some of the most common 'low-own-age' samples.

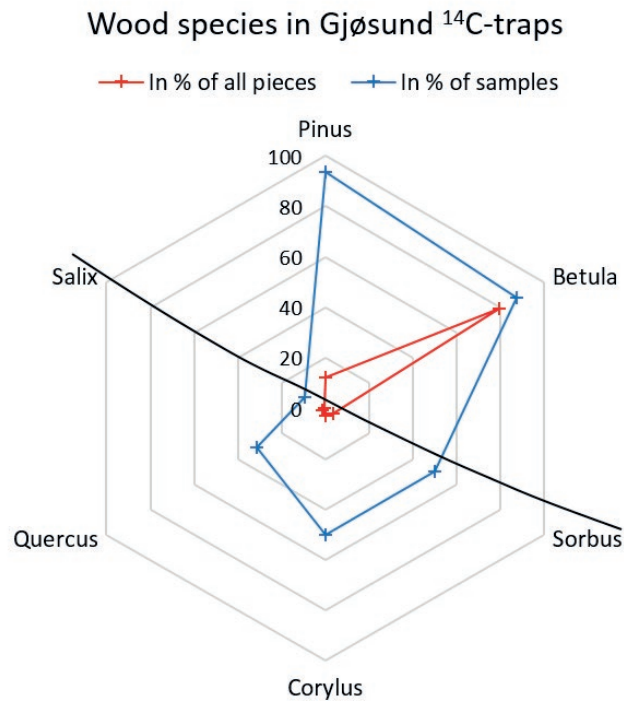
In strip, map and sample archaeology discussing own age and contextual age is seldom a matter of reaching any secure conclusions. In the Gjøssund case, the strategy was to select samples with a low own age in order to date the contents of visible context, hoping that the context would not be contaminated. It turned out that among the  $^{14}\text{C}$  samples, three returned very old dates. Of these three, two were *corylus avellana* – hazel, although only three hazel samples were dated. There is in other words a possible tendency in this specific case that *corylus avellana* returns early dates.

#### THE INTERPRETATION AND RELATION OF SUB CONTEXTS CONTAINING $^{14}\text{C}$ SAMPLES

The multi-functional Gjøssund house is a sub-context and it is not unreasonable that when the house was pulled down, it became a flat house mound sufficiently respected not to be much disturbed until modern times. To later generations it may indeed have marked the place. It is possible, therefore, that samples related to postholes and hearths represent the time when the house was lived in. In addition, the time when it was pulled down and made a monument may also be represented by the context. Formally, however, the  $^{14}\text{C}$  samples date universal time, which by implication is only linked to one or probably more contexts. If we want to understand precisely why a certain trap contains what it does, we have few significant variables to support our interpretation. In the Gjøssund case, however, the date, the frequency of species and their presence in samples might be a clue. Nearly 80 % of the charcoal pieces are from *betula*. Among the infrequent species, *pinus* is found in nearly all traps. *Corylus avellana* is present in 50% of the traps, but there are no more than 22 pieces in total. In all traps but one, there are only one or two pieces (see fig. 5). Three pieces from three different traps have been dated and they returned two very old dates. It seems likely, therefore, that hazel may in some cases represent activities that predate the house. Stratigraphical proof that this is the case does not exist.

#### THE VARYING NUMBER OF $^{14}\text{C}$ SAMPLE TRAPS

The Early Iron Age house from Gørding Hede (see Andersen 1951; Herschend 2009:150–52) was so well-preserved that it can be argued that the house was emptied except for the kitchen ware around the hearth before it was burnt down, pulled down and turned into a flat mound. Tidying up the scene of fire, perhaps pulling out posts from their holes may be expected to have produced a number of  $^{14}\text{C}$  traps. Despite this possibility, neither a protective mound nor the floor layer itself were preserved at Gjøssund. However, the lower parts



	Pinus	Betula	Sorbus	Corylus	Quercus	Salix
In % of all pieces	12,1	79,4	3,6	3,0	1,5	0,4
In % of all samples	93,8	87,5	50,0	50,0	31,3	9,4

Fig. 5. Wood species in Gjøssund <sup>14</sup>C traps, diagram and table.  
[http://files.webb.uu.se/uploader/92/Fig\\_5.jpg](http://files.webb.uu.se/uploader/92/Fig_5.jpg)

of some demolition traps may still have been found when the house was excavated. This means that wood that may have burnt when the house was turned into a monument could be over-represented. In <sup>14</sup>C terms, points in time close to the abandonment may thus be too frequent. In addition to demolition traps, digging the postholes when the house was built may have trapped a number of samples. In many cases, moreover, it may be reasonable to think that as life went on in a house the number of traps grew owing to repairs and changes.

## Universal time depicted by preserved organic material

It is obvious that universal time is not by default depicted correctly by the preserved organic material. This is partly a matter of fluctuations in the calibration curve and isotope relations, partly a matter of the human sample production rate, partly a matter of the relative number of effective  $^{14}\text{C}$  sample traps such as holes in the ground on Iron Age settlements (Herschend 2009:20–21) and partly a matter of preservation, which is usually poor in strip, map and sample archaeology.

The archaeological discussion of the complex relations between these parameters is a matter of defining the archaeological context in terms of characteristics, and chronological frames. Keeping track of these parameters will result in some more or less typical models with a relation to the calibration curve. Developing these models is one of the long-term goals of modern Iron Age archaeology. Initially, however, probability distributions may be referred to two basic models: one in which a period of time looks like a *plateau*, and one in which it looks like a *peak* (see fig. 6).

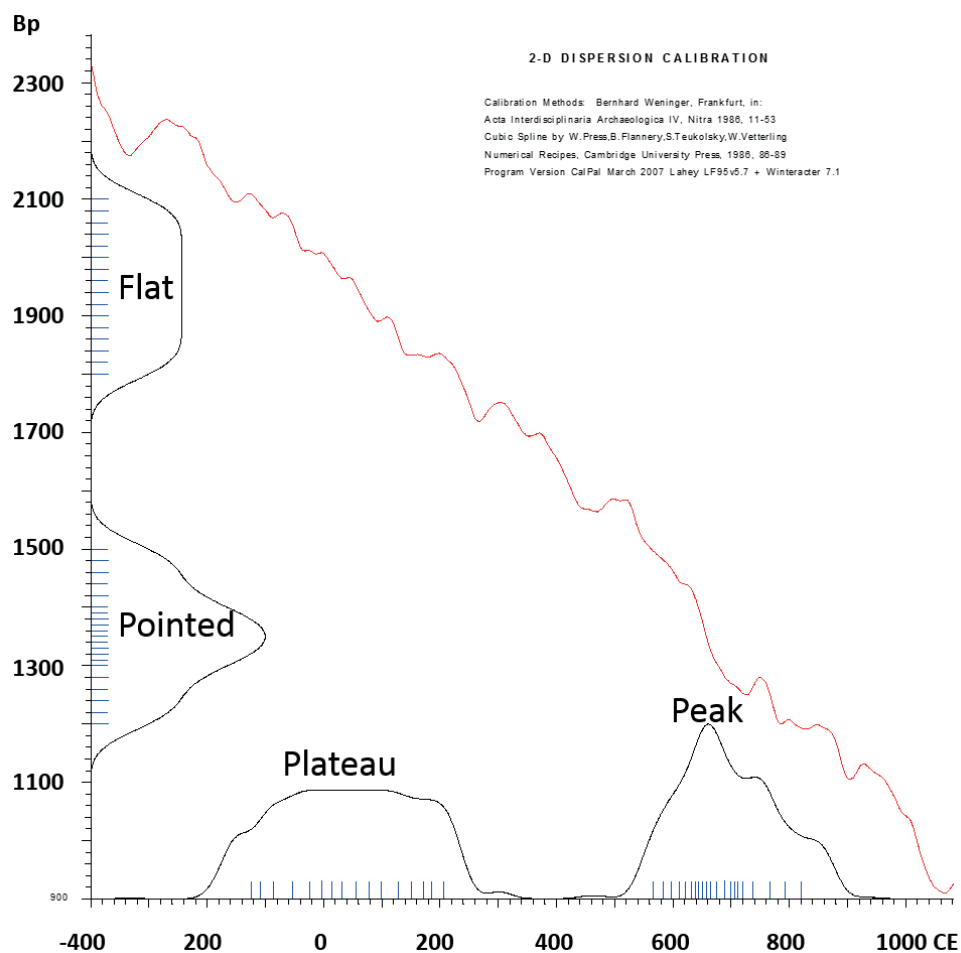


Fig. 6. 300  $^{14}\text{C}$  years dated regularly every 20th  $^{14}\text{C}$  year, produce a flat symmetrical pattern. If, in the central part of the period, years are more densely dated, e.g. with one date every 10th year, the symmetrical pattern becomes pointed. When calibrated, the probability distributions look like a plateau or a peak.

[http://files.webb.uu.se/uploader/92/Fig\\_6.jpg](http://files.webb.uu.se/uploader/92/Fig_6.jpg)

A peak distribution signifies a dynamic period with many dated events. A plateau distribution signifies a regular series of events. Several settlements dating from 100 BCE to 400 CE have a peak period. Earlier and later settlements look more like plateaus (see fig. 7A–H). Settlements characterized by peaked distributions are interesting because they are dynamic, but difficult to date as a period, since universal time is depicted unevenly and without obvious borders. A ‘plateau mountain’ is the expected period silhouette if contextual time corresponds to universal time. In stable and thus less dynamic periods we may expect plateau distributions. As expected, the Gjøssund probability distribution is rather flat, but interesting as a distribution not least because of the difference between the  $^{14}\text{C}$  years and the calibrated calendar years, see below fig. 8. From a methodical point of view, moreover, it is an advantage that the distribution is not dynamic.

### SAMPLE PRODUCTION RATE

The production of organic waste varies. Some periods and economic systems produce more than others. In the Gjøssund case, however, we have little indication that production was anything but stable. Nevertheless, we may want to exclude samples from early or late features in order to define samples of the beginning or the end of the life of the house. Selecting true occupation dates tends to stress the division between the primary house samples trapped in postholes, pinholes and hearths when they were constructed and secondary

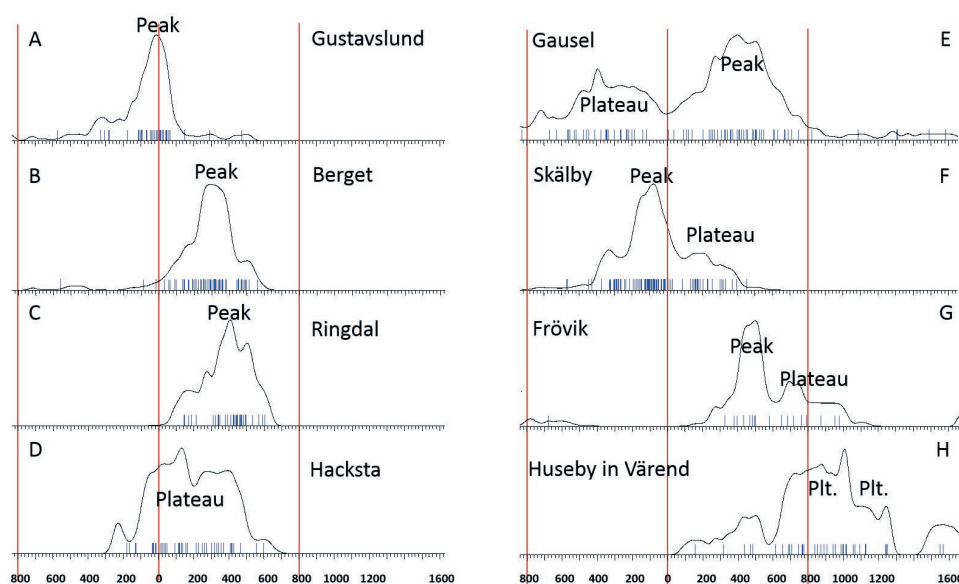


Fig. 7. In peaked distributions, dates tend to be frequent in the central part of the settlement period. Plateau distributions depict time in a more constant way. There are also mixed and blended distributions. For Gustavslund, see Aspeborg, 2012; Aspeborg and Strömberg, 2014. For Berget, see Göthberg *et al.* 2014. For Ringdal, see Gjerpe and Østmo, 2008. For Hacksta, see Lagerstedt and Lindwall, 2008; Norr, 2008. For Gausel, see Børshiem and Soltvedt, 2002. For Skälby, see Aspeborg, 1999; Onsten-Molander, 2008; Korpås and Wikborg, 2012. For Frövik, see Hamilton, 2001. For Huseby in Varend, see Söderberg and Nylén, 2009. [http://files.webb.uu.se/uploader/92/Fig\\_7.jpg](http://files.webb.uu.se/uploader/92/Fig_7.jpg)

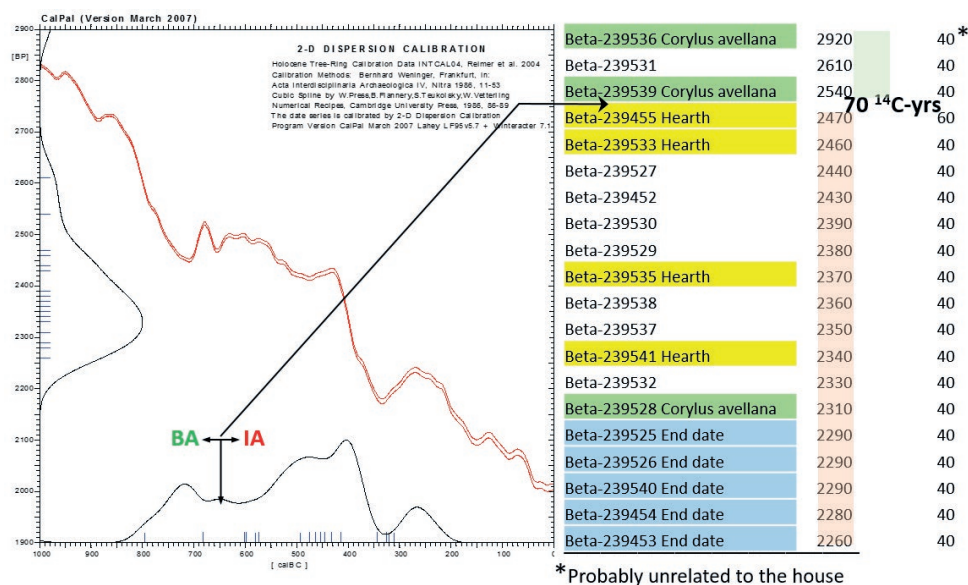


Fig. 8. A general overview of the  $^{14}\text{C}$  dates from Gjosund. The oldest date falls outside the diagram.

[http://files.webb.uu.se/uploader/92/Fig\\_8.jpg](http://files.webb.uu.se/uploader/92/Fig_8.jpg)

samples, which may have been trapped in any hole or depression. Repairing a house may thus be seen in two different ways, as a part of continuously living in the building or as a way of understanding life in the house as divided into a primary and a secondary phase. However, understanding settlements as being divided into phases has been criticised, for instance by Holst (2004A & 2004 B). In fact, it is typical of the Iron Age house that it may be rebuilt by pulling down the old house and building up the new one simultaneously (Herschend 2009:141). In the Gjosund house there is no point in figuring out a production rate or a primary and secondary house phase.

## RELATIVE NUMBER OF EFFECTIVE $^{14}\text{C}$ SAMPLE TRAPS

Production rate and the relative number of effective traps covariate at Gjosund during the lifetime of the house. Additionally, its abandonment may have turned a large number of holes into effective traps. The relative number therefore starts with many rather ineffective traps during the construction phase when little charcoal is present. During the occupation and repair phase when there is more charcoal, there are fewer, but also more successful traps. In the end, all functioning holes and hearths may have become traps.

## SAMPLE PRESERVATION

The preservation of the samples is first of all a matter of very many samples that have been lost. Samples from the house floor, for instance, were destroyed with the floor layers. Nevertheless, there is a great point in understanding the way sample preservation works. For instance, in the house from Gene in Ångermanland, samples from postholes gave early dates and samples from the hearths gave late dates. This pattern has been explained with reference to the house being built in a virgin forest using very old trees trunks split into

manageable roof-supporting posts. Charring these posts to protect them from rotting and burying them in the postholes preserved old dates on a site with no prior occupation (Norr 1998). Diinhoff and Slinning (2013:72f.) being aware of the possibility that postholes may or may not preserve old pine wood, prefer to date birch, which was not used as roof-supporting posts, but mostly as firewood .

The theme series from I:I to III:III, Tab. 1, consists of straightforward, but also difficult archaeological points. They are difficult since archaeology has not yet developed a general method for treating a new and closely dated material with little complexity and precision in contextual terms. A piece of charcoal or a seed may have ended up in a hole for a number of different reasons and in many different ways, and we do not know why or in which way. Birch was used continuously and preserved by chance. When it comes to understanding  $^{14}\text{C}$  samples we are still in an archaeological development phase with few systematic comparative studies of vast comparable materials. In the 19<sup>th</sup> century, comparative artefact studies were in need; today, in the 21<sup>st</sup>, there is a need to study mass  $^{14}\text{C}$  -materials for instance from European postholes. It is possible that better ways of handling  $^{14}\text{C}$  dates from a statistical point of view may be helpful.

## How should a $^{14}\text{C}$ probability distribution be treated?

### SCIENTIFIC PARAMETERS

Diinhoff and Slinning were able to send no less than 20  $^{14}\text{C}$  samples to the radiocarbon laboratory and apart from one, all dates had 40  $^{14}\text{C}$  years as their standard deviation. The deviant date had 60  $^{14}\text{C}$  years (2013:Fig. 5). We accept these deviations and in fact, the only scientific parameter that we can and must take into consideration is the relation between the  $^{14}\text{C}$  dates and the calibration curve.

### OVERVIEW OF PROBABILITY DISTRIBUTIONS

If we look at the overall probability distribution (see fig. 8), it seems that the Gjosund house could at least partly be contemporary with the almost horizontal part of the calibration curve in the 6th and 5th c. BCE. Nevertheless, the three oldest dates have their central (centroid) values well before the horizontal phase. Two of them, moreover, date the uncommon species *Corylus avellane*. This suggests that they are chronologically valuable contaminations – old pieces of hazel, charred before the house was built, but nevertheless trapped in its postholes.

When we look at the latest dates it becomes apparent that there are five within the last 30  $^{14}\text{C}$  years, i.e. twice as many as expected. This means that the distribution may perhaps be compatible with an abandonment event with many sample traps. If we add hearth dates to the overview it becomes apparent that they are not late. Gjosund hearths, although they represent the occupation

phase, are not prolific traps for end dates. Moreover, dates from the postholes are not dating posts with a high own age. As traps, hearths and postholes are different, but together they seem to date the occupation phase quite well. The overview of the probability distribution, therefore, suggests that we should discard the three earliest dates as contaminations and keep the rest. The new distribution is in accord with a reasonable interpretation of the archaeological context.

## BAYESIAN-AIDED CHRONOLOGY

Probably the general interest in Bayesian statistics has reached archaeology in tandem with a growing interest in ‘archaeological science’, see e.g. Killick (2014:159f. and 161f.) and a more theoretical discussion about the acceptance of the Bayesian approach in Steel (2000). Nevertheless, it is the large amounts of new dates that prompt new questions. Data request us to use information in a systematic way and with precision in relation to large sets such as the probabilities behind the curves in fig. 008. Bayesian statistics has the ability to answer such questions and is especially useful as an analytical tool when researchers cannot intuitively come to terms with the complexity created by large datasets. I have chosen the BCal calibration tool to handle chronological questions.<sup>3</sup>

To pose a question that may return Bayesian probabilities, archaeologists need to have some sort of *prior* factual knowledge about a set of <sup>14</sup>C tests. When these priors are fed into the BCal tool, it will return probabilities that are *posterior* to our *prior* knowledge (see diag.1).

In the present case, prior knowledge has been established by the discussion of the first three areas of the methodical procedure. This discussion has allowed us to define datasets with an *a priori* chronological relation to the house remains. We can define three relevant <sup>14</sup>C datasets:

1. The Iron Age dates, because generally speaking, they date the house.
2. To this group we may add the three early dates as expressions of an earlier period of site use, that is, activities that are *older* than the house. The second dataset, therefore, consists of two groups, the older Bronze Age dates and the house-contemporary Iron Age dates.
3. We may argue that the three old dates do not represent a period. Instead, they are the result of a sporadic presence on the site. In that case, the last Bronze Age date represents an event that happened on the spot where the house was eventually erected. The third dataset, therefore, consists of two groups: the last Bronze Age date and the Iron Age dates.

By means of these sets we have defined three *a priori* descriptions of the chronology of the house. One in which only the values from the lifetime of

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<sup>3</sup> The BCal team is comprised by Caitlin Buck, Geoff Boden, Andrés Christen, Gary James and Fred Sonnenwald. The URL for the service is <http://bcal.sheffield.ac.uk>. See Buck *et al.* (1999).

Relative chronological information									
<div> <div>Gjoesund 3rd dataset</div> <div> <div>beta 2</div> <div>Gjs House</div> </div> <div>alpha 2</div> <div> <div>beta 1</div> <div>Before Gjs house</div> </div> <div>alpha 1</div> </div>									
Radiocarbon data and absolute chronological information									
group label ordered									
Before Gjs house no									
boundary parameter label absolute prior									
alpha 1 no absolute prior information									
theta label absolute prior calibration curve lab number mean error outlier probability delta-R mean delta-R error									
theta 3 no absolute prior information Atmospheric 2004 Beta-239539 2540 40 0 0.0 0.0									
boundary parameter label absolute prior									
beta 1 no absolute prior information									
group label ordered									
Gjs House no									
boundary parameter label absolute prior									
alpha 2 no absolute prior information									
theta label absolute prior calibration curve lab number mean error outlier probability delta-R mean delta-R error									
theta 4 no absolute prior information Atmospheric 2004 Beta-239455 2470 60 0 0.0 0.0									
theta 5 no absolute prior information Atmospheric 2004 Beta-239533 2460 40 0 0.0 0.0									
theta 6 no absolute prior information Atmospheric 2004 Beta-239527 2440 40 0 0.0 0.0									
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theta 20 no absolute prior information Atmospheric 2004 Beta-239453 2260 40 0 0.0 0.0									
boundary parameter label absolute prior									
beta 2 no absolute prior information									

Diag. 1. An overview of the Gjøsund sample as it appears in BCal.  
[http://files.webb.uu.se/uploader/92/Dia\\_1.jpg](http://files.webb.uu.se/uploader/92/Dia_1.jpg)

the house are included, and two sets that represent activities, which took place before the house was built, as well as activities that took place in the house. Given these dates we may ask BCal about the beginning and the end of the Iron Age dates, inasmuch as that they represent the period in which the house was built, used and eventually abandoned. BCal suggests that we define the ‘highest posterior density periods’ as chronological regions within which the house with a 95% probability (P95) was built and eventually abandoned (see Tab. 2).

The third dataset is to be preferred because it uses the chronological information in the most satisfying way, inasmuch as it accepts that one of the samples date a point in time when the plot was used *before* the house was built. The length of the period in which the Gjøsund site was used at intervals is interesting, but not specifically so in relation to the house. The third set returns the shortest building period (see Tab. 02; fig. 9).

Rather than asking for the timespan during which the house was built or abandoned, archaeologists would like to know whether or not a house was standing in a certain year. We can ask that kind of question too, and two answers are interesting: 1) When was there a 50/50 chance that the house had been built or abandoned? 2) When was there a 95% probability (P95) that

Table 2. Three datasets representing prior chronological knowledge and the resulting BCal posterior density periods.

Dataset	Building time (P 95%)	Abandoning time (P 95%)
1) One IA period	From 484 to 403 BCE, 81 yrs	From 394 to 354 BCE, 40 yrs
2) A BA and an IA period	From 480 to 403 BCE, 77 yrs	From 394 to 354 BCE, 40 yrs
3) One BA event and an IA period	From 478 to 403 BCE, 75 yrs	From 394 to 354 BCE, 40 yrs

Table 2.

[http://files.webb.uu.se/uploader/92/Table\\_2.jpg](http://files.webb.uu.se/uploader/92/Table_2.jpg)

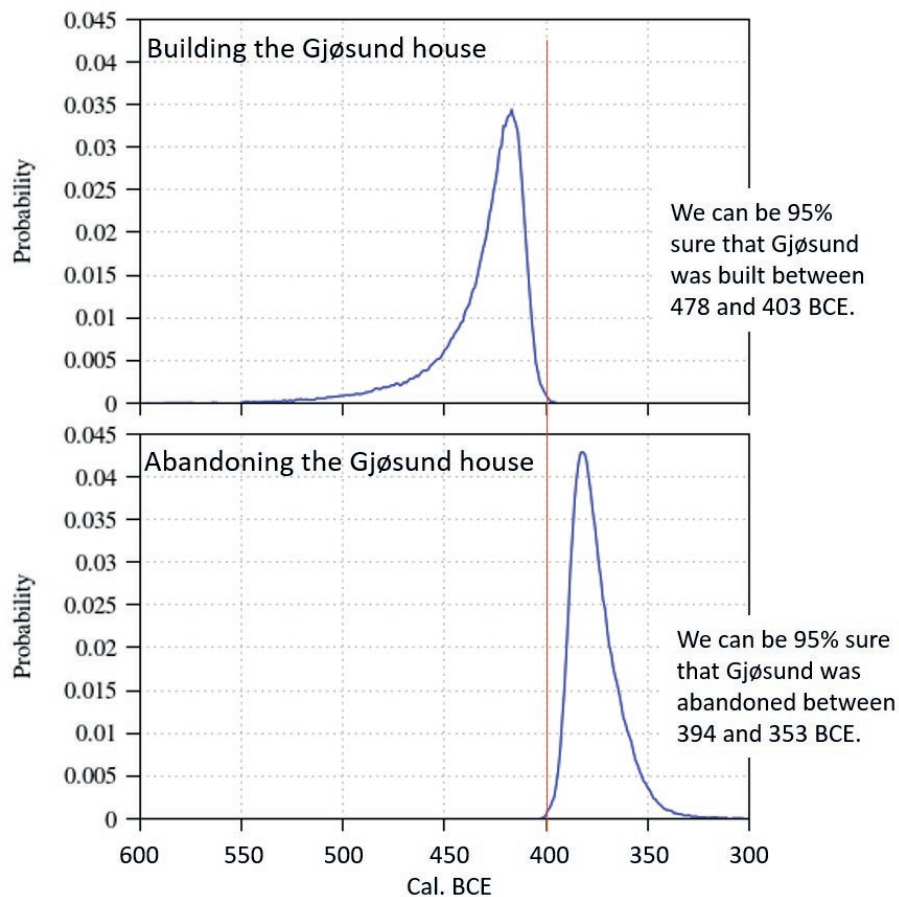


Fig. 9. Dating the beginning and the end of the Gjøsund house as periods of probability distributions.

[http://files.webb.uu.se/uploader/92/Fig\\_9.jpg](http://files.webb.uu.se/uploader/92/Fig_9.jpg)

the house had been built or abandoned? P95 is chosen simply because it is a reasonable level of significance. At Gjøsund the early 50/50 and P95 years are 424 and 408 BCE respectively. The late years are 378 and 360 BCE. This means that the house was more likely that not to have been built before 408, but not earlier than 424 BCE. When it comes to its final stage, the house was more likely than not to have been abandoned after 378, but not later than 360 BCE (see fig. 10). Given these buffers a lifetime of some 50 years for the Gjøsund house is not unreasonable.

As pointed out, there are five end dates in the Gjøsund series, all from postholes (see fig. 11). These dates may perhaps indicate that the holes acted as  $^{14}\text{C}$  traps for late dates linked to the abandonment of the house when, perhaps,

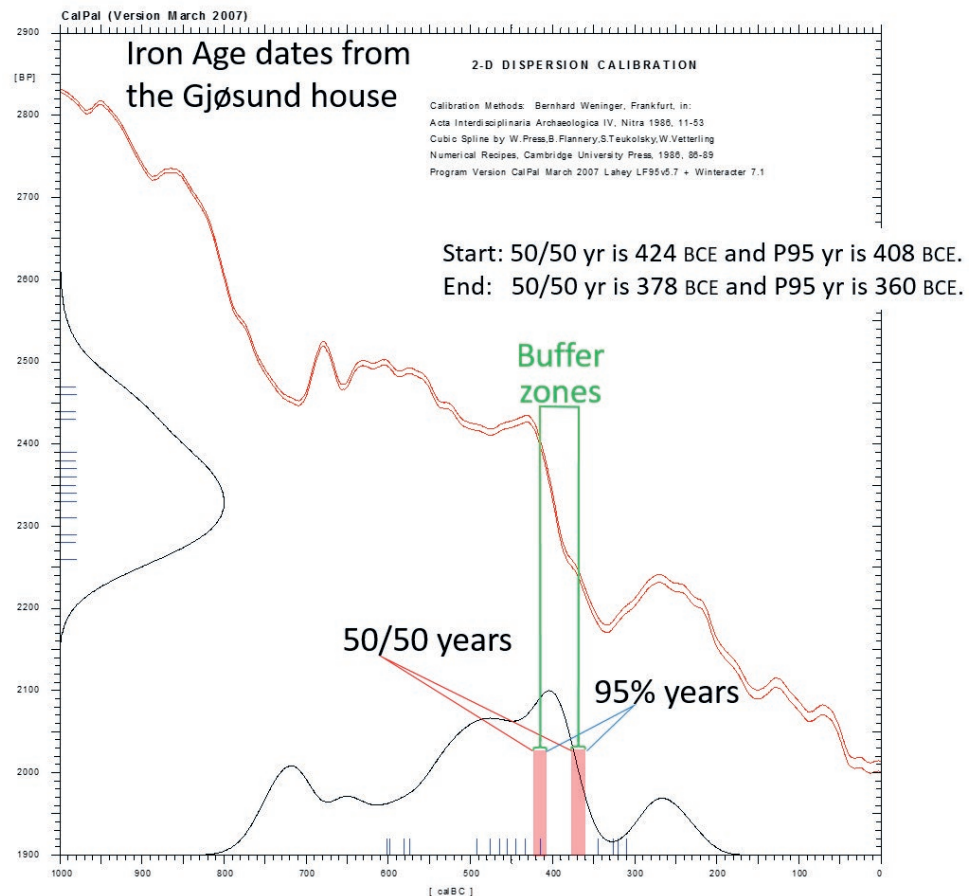


Fig. 10. Dating the Gjøssund house as a period within chronological buffers.  
[http://files.webb.uu.se/uploader/92/Fig\\_10.jpg](http://files.webb.uu.se/uploader/92/Fig_10.jpg)

it was burnt and/or pulled down allowing charred wood to be trapped in the depressions that appeared when the posts were pulled out of their holes. However, this pattern is not so distinct that it can be used to support a new chronological model, mainly because it is impossible to point out the dates that represent the end event or 'the funeral pyre of the house', rather than the last part of the occupation phase. If, for the sake of the argument, we suggest that the last five dates represent a distinct last part of the occupation period, the influence of the bend in the calibration curve becomes apparent (see fig. 11). The 50/50 values are the expected ones. Trying to date an end period, therefore, seems to be pointless.

## Discussion

If Diinhoff and Slinning had thought that hazel (*Corylus avellana*) would have been the optimal wood to date; since a hazel stool is often coppiced when the aerial stems are young, contaminations could have been so numerous that they would have been difficult to see. If the traps that caught late dates had not existed, then the end dates could have been difficult to establish. If

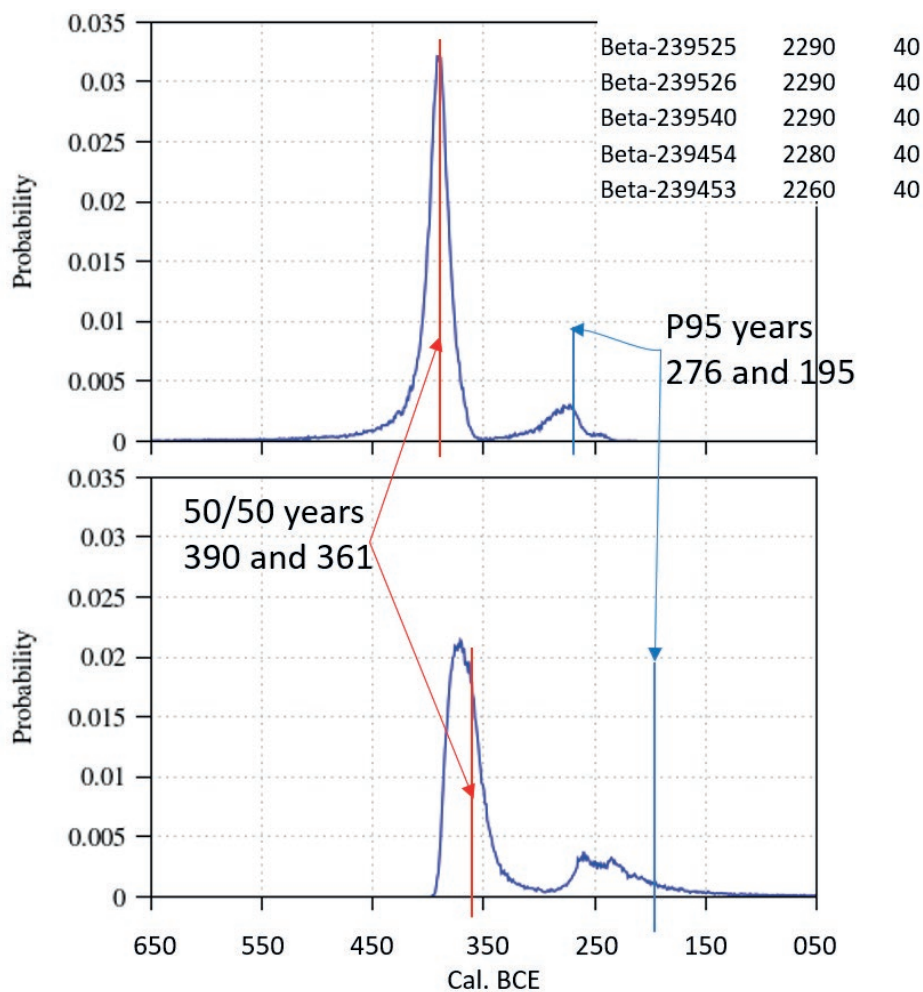


Fig.11. Looking at the last  $^{14}\text{C}$  dates from Gjosund as an 'end period' demonstrates the problems created by the bend in the calibration curve. Given the dates, the calibration curve and our knowledge of the house remains, there is no point in trying to understand the five dates as representing a period in their own right.  
[http://files.webb.uu.se/uploader/92/fig\\_11.jpg](http://files.webb.uu.se/uploader/92/fig_11.jpg)

the house had been built 50 years earlier, a number of difficulties caused by the calibration curve, comparable to those that signify the end dates, would have been obvious. As it happened, some difficulties became apparent, such as interpreting the end dates, while others, such as handling contaminations from earlier activities, found a solution in accordance with the archaeological context.

Diinhoff and Slinning's original hypothesis gained considerable support from the Bayesian approach. It is possible to date a single Early Iron Age house, echoing the Bronze Age, even though it stood for no more than two or three generations. The case was created by the sound decisions taken by Diinhoff and Slinning. These decisions, such as dating many samples and preferably dating *betula*, suggested that it was reasonable to assume that the dating project would succeed in proving their hypothesis. None the less, an intuitive analysis of the probabilities of the  $^{14}\text{C}$  values was not sufficient. It took new *a priori* knowledge fed into the Bayesian theorem to support the hypothesis, and the

result was counterintuitive. Few would have guessed that  $^{14}\text{C}$  tests can date a two-generation house, especially when the building stood in a period marked by low-precision  $^{14}\text{C}$  dates.

The way the *a priori* information in Tab. 02 returns different Bayesian probabilities when tested exemplifies the importance of the *a priori* discussion as indeed a procedure that must be quite circumstantial before it can become a routine. Consequently, the section on *Bayesian-aided chronology* was relatively short. Nevertheless, the analysed datasets, characterized by different priors, resulted in typical ‘sliding’ posterior probabilities from 483–403 to 478–403 BCE in Tab. 02. On ‘sliding’ see Yodkowski (2016).

It was not possible to find a distinct chronological end pattern although the hypothesis that the house came to an end through some kind of abandonment rite is not entirely impossible. Nevertheless, a case study that aims at showing the benefits of methodical development must come to an end in exactly this way: proposing a *possible* hypothesis and finding it *impossible* to prove – for archaeological and/or scientific reasons.

The limits of a contextual analysis of a historical phenomenon must always be pointed out. In this case, the contextual anchoring of the end of the period in which the house was used was weak and the bend in the calibration curve created probability distributions that were inconsistent with a specific and coherent ‘end event’.

Having pointed out the inherent insecurity of the archaeological context it is easy to suggest that new dates from Gjesund may change the dating of the house. Nevertheless, Hans Hildebrand’s opinion when he was criticized in the 1870s for accepting the patterns revealed by the source material, rather than stressing the possibility that future finds may change the pattern, still holds true: “However, it is difficult to try to refute conclusions drawn from what one knows by means of conclusions drawn from what one do not know” — *Det är dock vanskligt att söka häfva de slutsatser, man drager från det man vet, med hjälp at slutsatser dragna från det man inte vet* (Hildebrand 1882:63).

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