# Quantifying Uncertainty in Expert Archaeological Dating Evidence

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https://sheffield.ac.uk/mps/research/maths/queade

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# Quantifying Uncertainty in Expert Archaeological Dating Evidence

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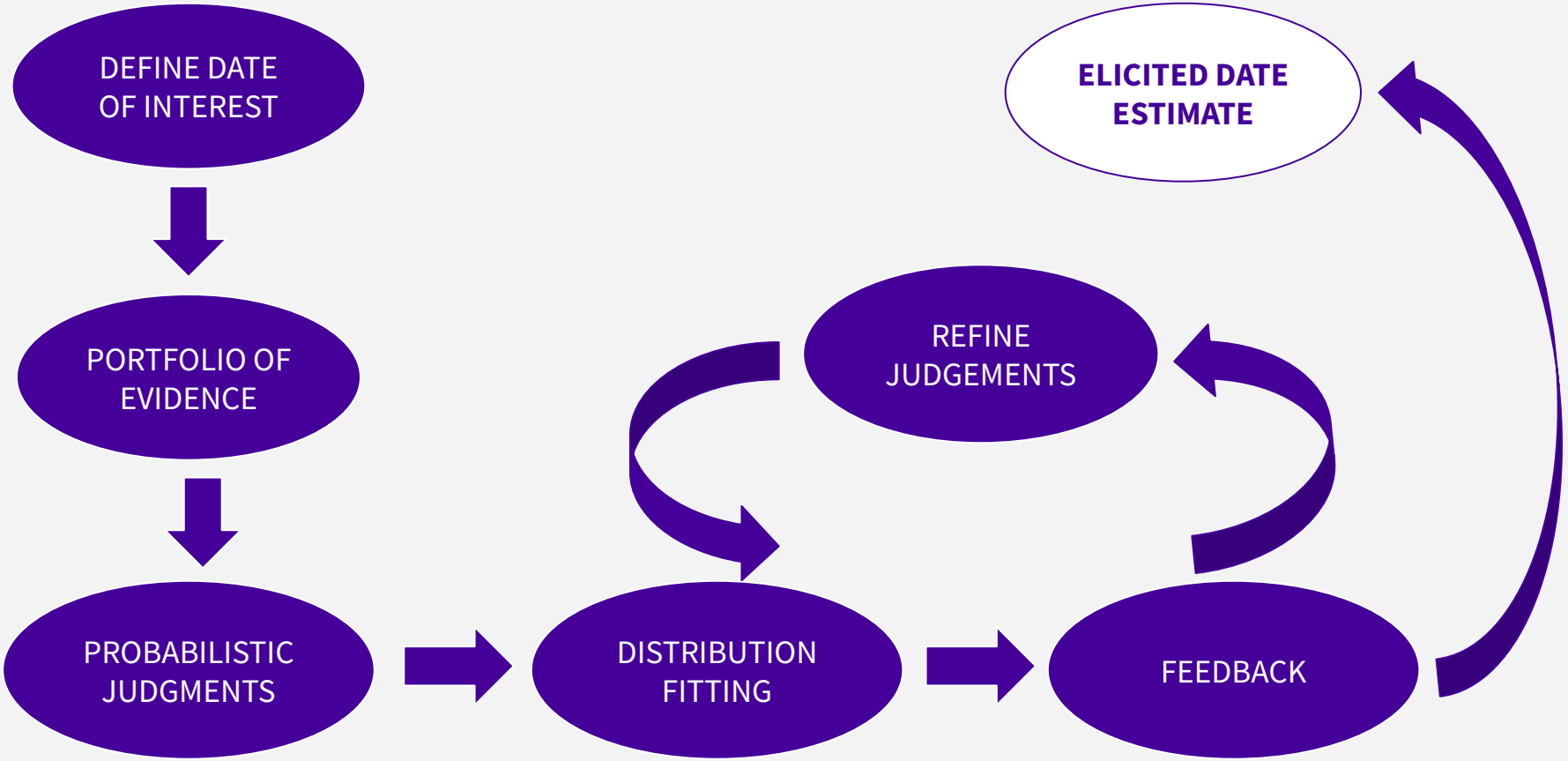
# What's the problem?

- Cultural finds are ubiquitous on archaeological sites …
- …and a primary source of dating evidence
- Such dates are typically uncertain and expressed as intervals e.g. probably 43-410 CE
- Site directors receive many such estimates and need to synthesise them
- Allen interval algebras are the obvious tool but…
    - It's not always obvious which date in the object's lifecycle has been estimated
    - Merging interval dates with other dating evidence (e.g. C14) is hard

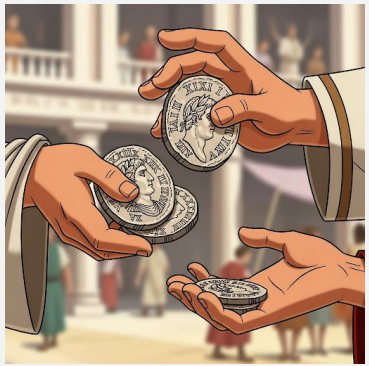
# Proposed solution

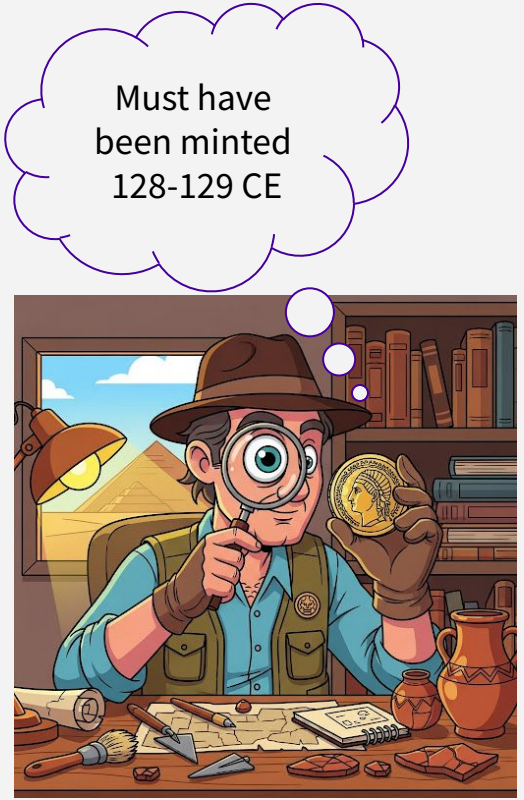
- Treat expert-derived date estimates more like laboratory-derived estimates
  - Focus on “chronometric hygiene”
  - Be clear precisely what each date estimate relates to
  - Formalise the uncertainty using probability distributions
- Sounds tricky, but…
  - We already takes lots of care with choosing samples for C14 dates
  - Other disciplines already quantify expert uncertainty routinely
- Tools known as knowledge elicitation are used where data are scarce or expensive
  - Suite of protocols and software to aid formalisation and visualisation of uncertainty
  - SHELF widely used in pharmaceutical, food security, environment, engineering, etc.

# Expert Knowledge Elicitation



# Dating contexts on the basis of finds evidence




Gemini Team, Google. 2023. “Gemini: A Family of Highly Capable Multimodal Models.” arXiv. Accessed August 15, 2025. https://arxiv.org/abs/2312.11805

# Dating context deposition with a coin find

‘The (...) coin (...) has been **assessed with confidence as ‘worn’**, in this instance equating to **approximately a couple of decades in circulation**. Since there was no other dating evidence for this context, **a deposition date** of **c.AD160–80** is suggested. There remains the **possibility** that the **extent of the circulation wear was overestimated, but not under-estimated**.’ (Speed and Holst, 2018; p. 507)

# Example 1 Deposition of Samian sherd 2460 in context 6766

Accession number: **AN2642 (SS8)**
Context number: **6766**
Site: **Crossrail XSM10** Liverpool Street Worksite, Liverpool Street, London
(https://doi.org/10.5284/1055107)

Stamp: **L. Coius Virillis**
Reading: **OFLCVIRIL**
Die: **12a**
Form: **18/37**
Production centre: **La Graufesenque**


https://archaeologydataservice.ac.uk/archiveDS/archiveDownload?t=arch-3331-1/dissemination/Photos/2015/Finds/059015008.jpg
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# Example 1 Portfolio of Evidence

- Earliest decoration styles used by ***L. Coius Virillis*** are all characteristic of form Drag. 37, which became available on the market only after **70 CE**
- All known dated sites where the vessels of this potter appeared were founded after **90 CE**

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- Styles of the decorations and form repertoire associated with ***L. Cosius Virilis*** stamps, suggested that the main period of activity for this potter was between **100 CE** and **120 CE**
- **Drag. 18/31** is a variant known to have succeeded an earlier 1st-century form at the beginning of the **2nd century**

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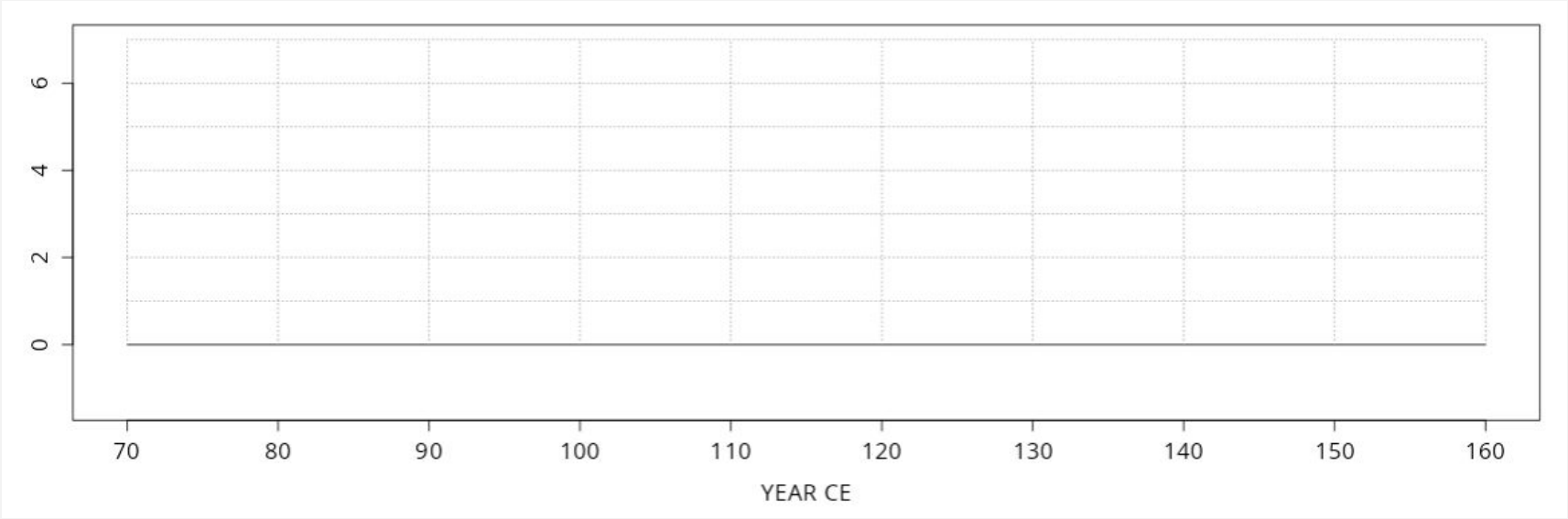
- Small but still recognisable quantities of ***La Graufesenque*** exports were on the market in Britain when Hadrian's Wall comprising a string of military camps was constructed from **122 CE** onwards
- At **160 CE** the ***La Graufesenque*** production centre was no longer active, as by this date, the exports completely disappear, including from from the Upper Germanic-Rhaetian Limes

# Example 1 Elicitation

**Earliest Date: 70 CE**

**Latest Date: 160 CE**

**11 x**  **1 x**  **= 1 in 11 chance or 9%**



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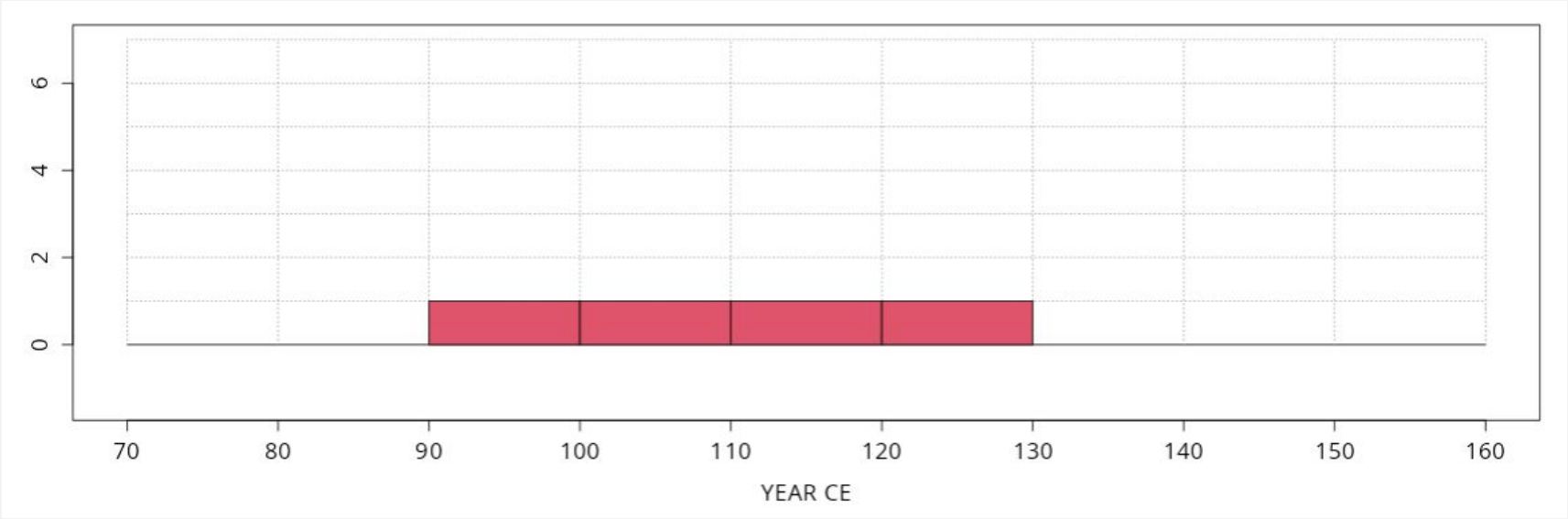

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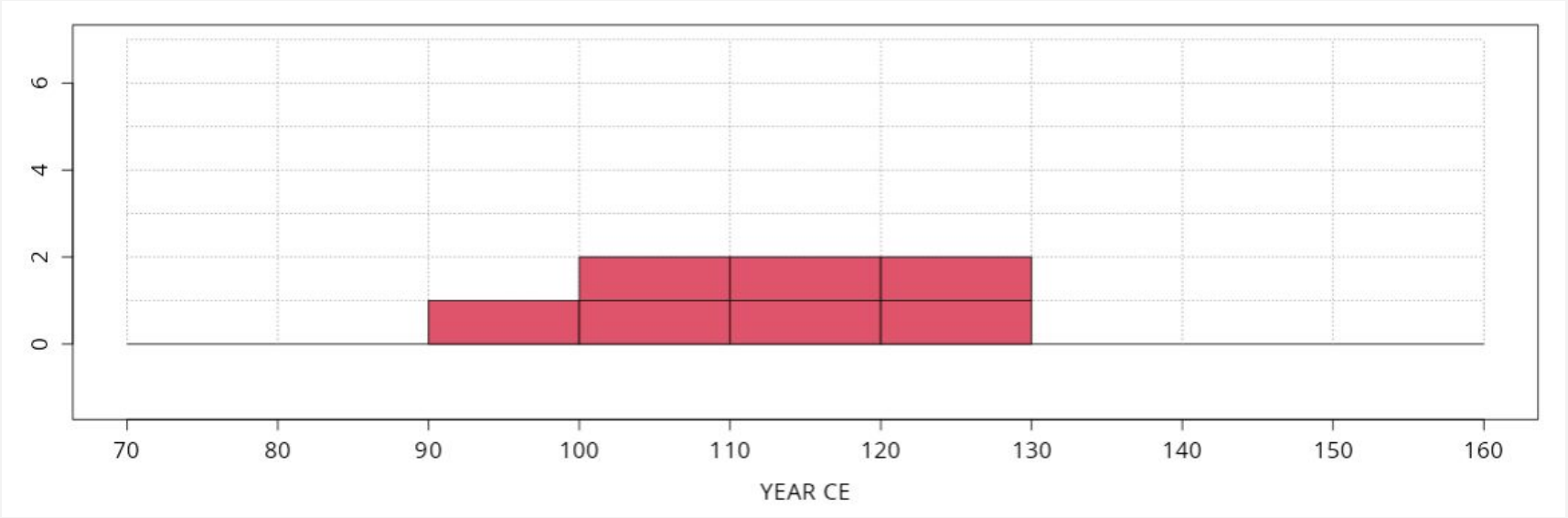

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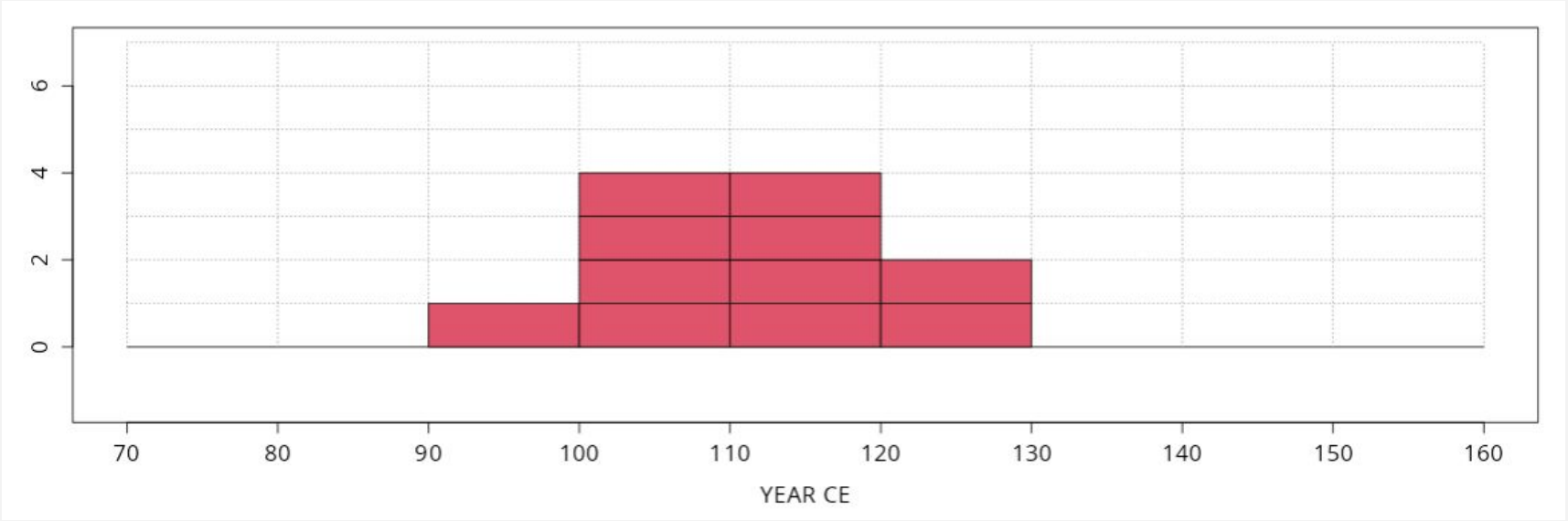
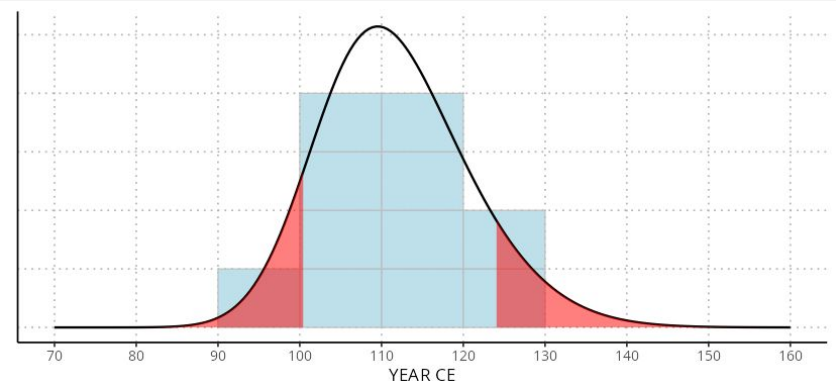
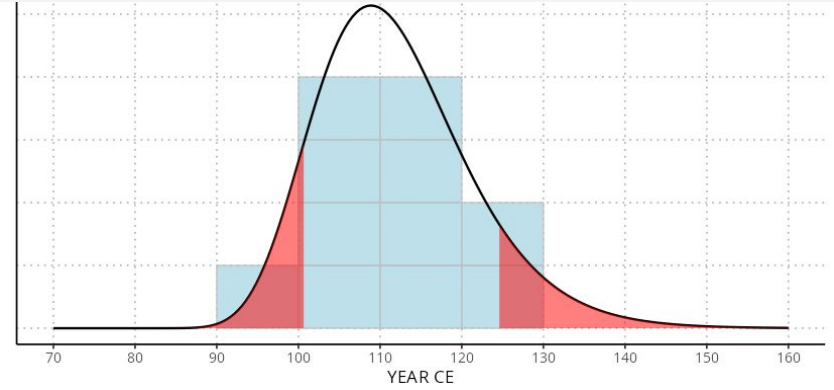
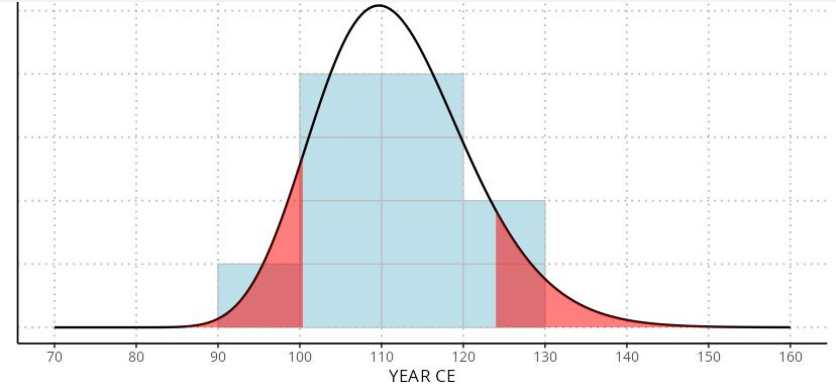
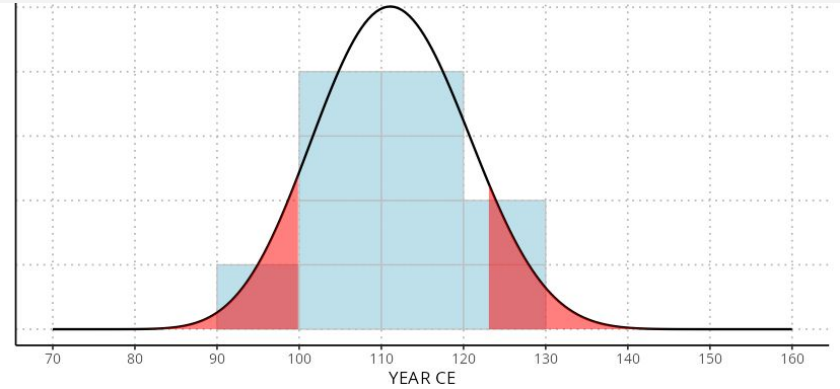


# Example 1 Distribution Fitting



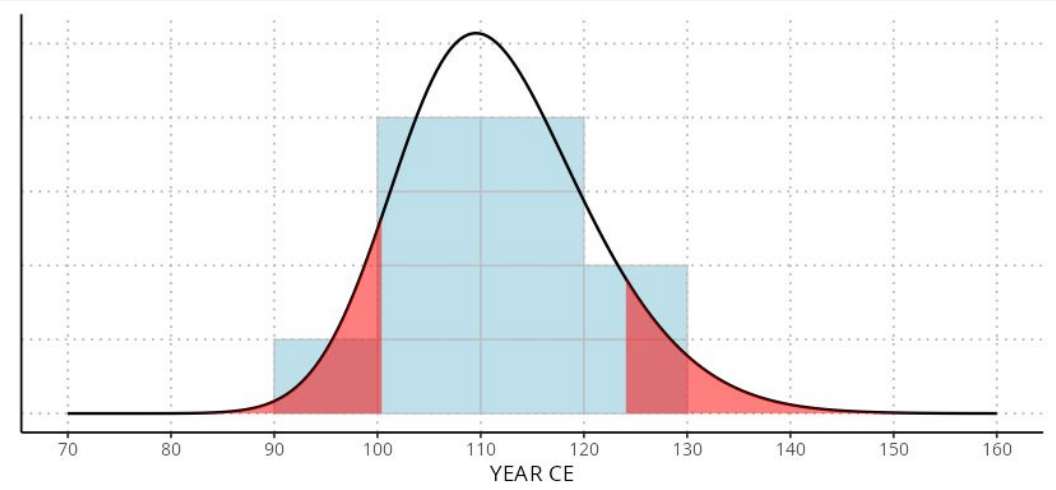



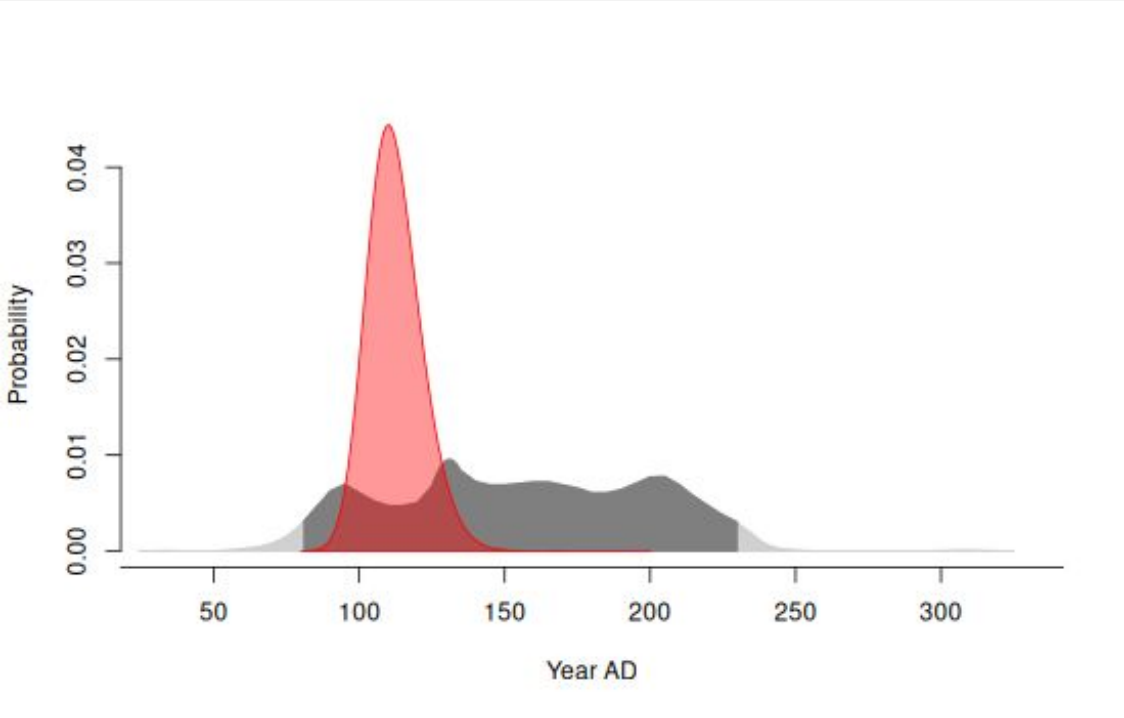
# Example 1 Feedback

- There is 10% probability that the sherd was deposited before 100 CE
- There is 10% probability that the sherd was deposited after 124 CE
- It is equally likely that the sherd was deposited before and after 111 CE




- There is 0.3% probability that the sherd was deposited before 90 CE
- There is about 3.6% probability that the coin was deposited after 130 CE

# Example 1: Comparison with radiocarbon date



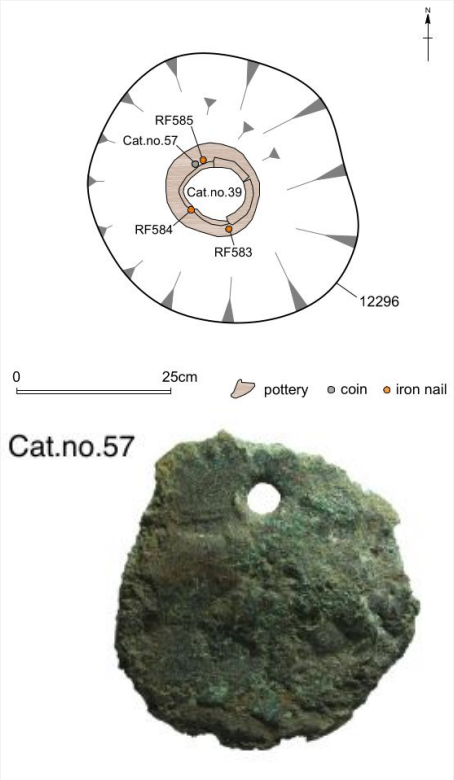

**SHERD AN2642** from context **6766** - elicited probability distribution

**95–132 CE (95%)**

**Beta-432454** - radiocarbon date from plant material recovered from context **6766**; posterior distribution **after Bayesian modeling:**

**55-150 cal CE (95%)**

# Example 2: Deposition of coin 57 in grave 269


Northern Archaeological Associates, 2021. Death, Burial and Identity: 3000 Years of Death in the Vale of Mowbray Digital Monograph, 2019. https://doi.org/10.5284/1050910; figures: 3.188-9, 3.223 Creative Commons Attribution 4.0 International License (CC BY 4.0).

# Example 2: Portfolio of Evidence

Catalogue number: **57**
Location: **Grave 269**

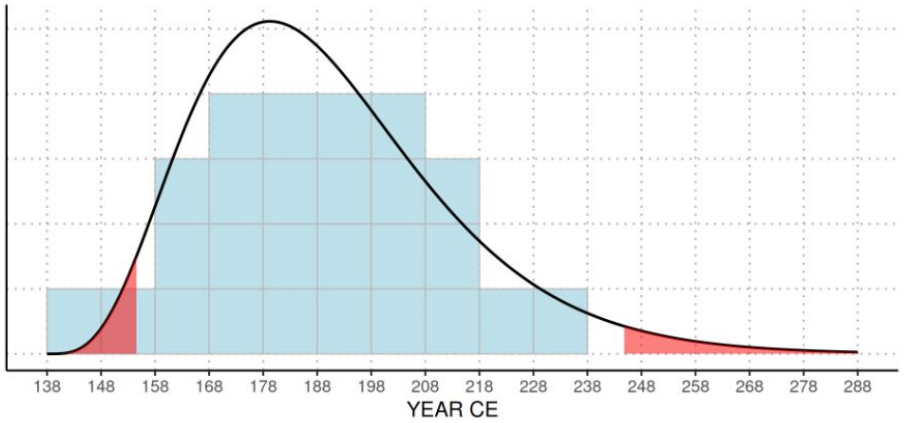
Context number: **12293**
Site: **Cataractonium**
(https://doi.org/10.5284/1050910)

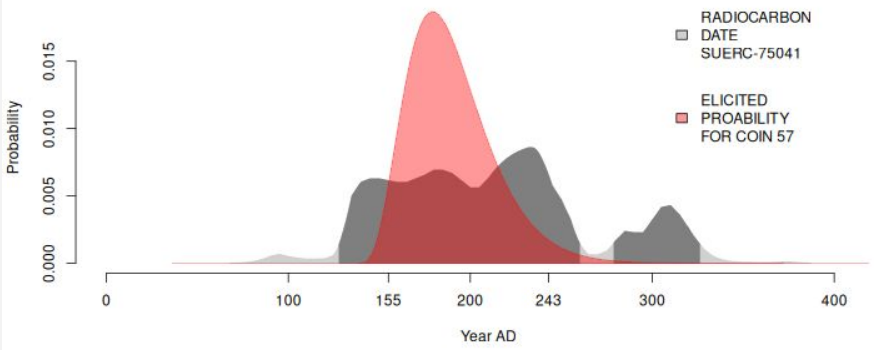
**Portfolio of evidence:**

- Originally identified as Pierced copper-alloy coin (Antoninus Pius 138-61 CE)
- Bronze coin of Antoninus Pius, based on the size probably an as or dupondius. The date is based on the dates of the reign of Pius.
- The wear cannot be exactly ascertained due to corrosion, but is probably 1-2 .
- Given that the coin is pierced, it could have been used as an ornament for an extensive period without being subjected to wear through use in circulation.


Modified from: Northern Archaeological Associates, 2021, https://doi.org/10.5284/1050910, figure: 3.189 Creative Commons Attribution 4.0 International License (CC BY 4.0).

# Example 2: Comparison with radiocarbon date




**COIN 57** from grave 269 - elicited probability distribution

**155–243 CE (95%)**

**SUERC-75041** - radiocarbon date for cremated human bone from grave 269

**127–261 cal CE (81.7%)**
**278–327 cal CE (13.7%)**
**1806±33BP**

# Future directions

- Extend the methodology to a broader range of artefact types, in collaboration with archaeologists in commercial and academic settings
- Combine expert date estimates for multiple finds with stratigraphic information via Bayesian chronological modelling
- Multiple experts elicitation, enabling aggregation of judgments to capture consensus and inter-expert variability
- Special cases where non-standard or bespoke distributions could be applicable

# Thank you!

**We are thankful to…**

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**The rest of the QUEADE team**

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Professor David Wigg-Wolf
Dr Allard Mees
Keith May

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