**Online Materials 1: Bayesian chronological models**

# Settlement and temporal dynamics during the LBK and post-LBK transition: A study of the loessic corridor from the Aldenhoven Plateau to Hesbaye (Germany, the Netherlands, Belgium)

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## 1. Structure of the supplement

This supplement contains the raw code, visual output, notes, and raw outputs for all Bayesian chronological models discussed in the Main Text. For an explanation of the rationale behind the model structures and the interpretation of these models, we refer the reader to the Main Text.

Each section contains the following elements:

- Model code
    - The CQL code for the Bayesian chronological model in OxCal v4.4.4 (Bronk Ramsey 2021);
- Notes
    - A discussion of dates and distributions with poor agreement indices or convergence.

The raw output of the models and the *Order()* queries (if applied) as given by OxCal v4.4.4 have been uploaded as separate files. A visual summary of the model output is also available separately. The naming of these files refers to the corresponding model. E.g., *Model_1_raw_output.csv* is the raw output of Model 1.

The visual summaries of the models feature the following lay-out. Grey distributions are posterior parameters and distributions and light grey distributions the calibrated dating ranges of radiocarbon dates prior to modelling; Solid circles are the means of posterior distributions and the transparent circles the means of calibrated dates prior to modelling. Solid diamonds are the calendrical date of simulated radiocarbon dates. Horizontal brackets show the two-sigma and three-sigma intervals of posterior distributions. Vertical brackets and OxCal verbs define the model structure. The agreement indices and convergence for all relevant distributions are also shown.

An overview of all radiocarbon dates, formatted according to the recommendations by Bayliss (2015) has also been included as *OM1_radiocarbon_dates.csv*. The bibliography for this file is combined with the bibliography of this document.

Throughout the Supplement, archaeological phenomena are referred to by the same abbreviations as those used in the Main Text. For convenience, a brief overview ot these abbreviations follows: Linearbandkeramik (LBK), Großgartach (GG), Rössen (RÖ), Blicquy/Villeneuve-Saint-Germain (BVSG), and Swifterbant (SWB).

## 2. Model 1

This Bayesian chronological model was formulated as an initial test for the overarching chronology for the Rhineland, Hesbaye, and Limburg proposed by Blouet *et al.* (2021, Tab. 3) and incorporates radiocarbon dates from all these areas.

## Model code

```
Plot()
 {
  Sequence("Chronozones")
  {
   Boundary("Start_RA")
   {
    Start("Start_Start_RA");
    Transition("Duration_Start_RA");
    End("End_Start_RA");
   };
   Phase("RA")
   {
    R_Date("GrA-27837",6170,45);
    Combine("Geleen-Janskamperveld_house_35")
    {
     R_Date("OxA-15601",6210,38);
     R_Date("GrA-27839",6110,45);
    };
    R_Date("OxA-15542",6204,35);
    R_Date("GrA-27836",6240,70);
    Combine("Geleen-Janskamperveld_house_13")
    {
     R_Date("GrA-27842",6180,50);
     R_Date("OxA-15600",6208,38);
    };
    R_Date("GrA-27838",6260,50);
    R_Date("BRAMS-1923",6142,33);
    R_Date("BRAMS-2611",6154,31);
    R_Date("UtC-13232",6312,35);
    R_Date("UtC-13234",6250,39);
    R_Date("UtC-13235",6229,33);
    R_Date("GrA-53554",6340,50);
    R_Date("GrA-52815",6150,35);
    R_Date("GrA-32979",6240,35);
    R_Date("Utc-7179",6230,70);
   };
   Boundary("Transition_RA_RM")
   {
    Start("Start_transition_RA_RM");
    Transition("Duration_transition_RA_RM");
    End("End_transition_RA_RM");
   };
   Phase("RM")
   {
    R_Date("OxA-2899",6290,70);
    Combine("Fexhe_pit_61")
    {
     R_Date("GrA-32977",6200,35);
     R_Date("GrA-33013",6130,35);
    };
    Combine("Fexhe_pit_89")
    {
     R_Date("GrA-33015",6150,35);
     R_Date("GrA-33017",6190,35);
    };
    R_Date("ECHO-2446.1.1",6150,80);
    Combine("Remicourt_pit_141")
    {
     R_Date("OxA-21409",6139,37);
```

```
  R_Date("OxA-21356",6213,36);
  R_Date("OxA-21355",6219,38);
 };
 R_Date("OxA-6688",6205,45);
};
Boundary("Transition_RM_RR")
{
 Start("Start_transition_RM_RR");
 Transition("Duration_transition_RM_RR");
 End("End_transition_RM_RR");
};
Phase("RR")
{
 R_Date("OxA-2896",6190,60);
 R_Date("OxA-2897",6230,60);
 R_Date("OxA-2898",6170,60);
 R_Date("OxA-2900",6160,60);
 R_Date("BRAMS-2602",6201,36);
 R_Date("OxA-5881",6060,55);
 R_Date("OxA-6690",6135,60);
 R_Date("GrA-33019",6120,35);
 R_Date("OxA-5878",6065,60);
 R_Date("OxA-6692",6215,45);
};
Boundary("Transition_RR_RF")
{
 Start("Start_transition_RR_RF");
 Transition("Duration_transition_RR_RF");
 End("End_transition_RR_RF");
};
Phase("RF")
{
 R_Date("OxA-5880",6070,60);
 R_Date("OxA-6691",6105,45);
 R_Date("OxA-6696",6110,45);
 R_Date("OxA-6697",6105,40);
 R_Date("OxA-6782",6205,60);
 Combine("Liège_Place Saint Lambert_pit 2")
 {
  R_Date("Lv-1341",6250,80);
  R_Date("Lv-1342",6270,100);
 };
 R_Date("OxA-5876",6060,55);
 R_Date("OxA-5877",6090,90);
 R_Date("GrN-64062",6035,40);
 R_Date("GrN-64059",6110,40);
};
Boundary("Transition_RF_RT")
{
 Start("Start_transition_RF_RT");
 Transition("Duration_transition_RF_RT");
 End("End_transition_RF_RT");
};
Phase("RT")
{
 R_Date("KN-1367",6410,45);
 R_Date("OxA-21410",6131,37);
 R_Date("OxA-21411",6108,37);
 Span("Duration_RT");
};
Boundary("End_RT")
{
 Start("Start_End_RF");
 Transition("Duration_end_RF");
 End("End_end_RF");
};
};
```

};

**Notes on Model 1**
As discussed in the Main Text, this model returns poor agreement indices (cf. Bronk Ramsey 1995; 2009a) for a relatively large number of radiocarbon dates. These dates are ordered by the chronozone to which they were attributed (cf. Blouet *et al.* 2021, Tab. 3) below.

*Rubané ancien*
GrA-27839: 6110±45BP; A = 33.7%; 5205-4906 calBC (CI=95.4%). The calibrated range of this date is younger and broader than the modelled range. The date was performed on a charred seed found in a settlement feature at Geleen-Janskamperveld (Van der Velde 2008). A potential intrusive date cannot be excluded.

BRAMS-1923: 6142±33BP; A=52.6%; 5210-4995 calBC (CI=95.4%). This date too has a calibrated range which is significantly broader and younger than the modelled range. The date was performed on the combined $C^{16}$ and $C^{18}$ fraction of absorbed lipids in an LBK sherd from Geleen-Janskamperveld (Casanova *et al.* 2022). The sherd might be intrusive.

UtC-13232: 6312±35BP; A=38%; 5360-5214 calBC (CI=95.4%). The calibrated range of this date is older than the modelled range. The sample was a seed from a settlement context at Niederkassel-Uckendorf (Heinen 2010). A residual date cannot be excluded.

GrA-53554: 6340±50BP; A=31.1%; 5471-5212 calBC (CI=95.4%). The calibrated range of this date is also older than the modelled range. The date was performed on charred seeds from a post hole at Stein-Hedekampweg (Porreij-Lyklema and Van Wijk 2012). Potentially a residual date.

*Rubané moyen*
OxA-2899: 6290±70BP; A=45.5%; 5470-5048 calBC (CI=95.4%). The modelled range of this date falls in a time range which has a low probability density for the calibrated range. The date was performed on a charred cereal from a settlement feature at Langweiler 8 (Hedges *et al.* 1993). The combination of a relatively large error margin in the dataset and a relatively narrow modelled range may be the cause of the poor agreement index.

*Rubané récent*
OxA-5881: 6060±55BP; A=51.3%; 5208-4797 calBC (CI=95.4%). The modelled range of this date is old relative to the calibrated range. The date was performed on a hazelnut (or potentially a bulk sample of hazelnuts) from a settlement feature at Darion (Jadin and Cahen 2003). A residual date cannot be excluded.

*Rubané final*
OxA-5876: 6060±55BP; A=59.3%; 5208-4797 calBC (CI=95.4%). The modelled range of this date is old relative to the calibrated range. The date was performed on cereals (potentially a bulk sample) from a settlement feature at Oleye “Al Zepe” (Jadin and Cahen 2003). A residual date cannot be excluded.

GrN-64062: 6035±40BP; A=10.5%; 5041-4800 calBC (CI=95.4%). The modelled range of this date is old relative to the calibrated range. The date was performed on charred seeds from a settlement feature at Maastricht-Cannerberg (Van Wijk 2016). An intrusive date cannot be excluded.

*Rubané terminal*
KN-1367: 6410±45BP; A=0.0%; 5476-5308 calBC (CI=95.4%). The modelled range of this date is young relative to the calibrated range. The date was performed on a cereal from Lamersdorf-Inden (cf. Jadin and Cahen 2003). A residual date cannot be excluded.

## 3. Model 2

This Bayesian chronological model was formulated to check the regional typochronology from Blouet *et al.* (2021) for Hesbaye with only those radiocarbon dates from the area and assemblages for which the typochronology was formulated.

## Model code

```
Plot()
 {
  Sequence("Blouet chronology")
  {
   Boundary("Start Blouet 1")
   {
   };
   Phase("Blouet 1")
   {
    R_Date("GrA-32979",6240,35);
   };
   Boundary("Transition Blouet 1/2")
   {
   };
   Phase("Blouet 2")
   {
    R_Date("ECHO-2446.1.1",6150,80);
   };
   Boundary("Transition Blouet 2/3")
   {
   };
   Phase("Blouet 3")
   {
    Combine("Fexhe_pit_61")
    {
     R_Date("GrA-32977",6200,35);
     R_Date("GrA-33013",6130,35);
    };
    Combine("Fexhe_pit_89")
    {
     R_Date("GrA-33015",6150,35);
     R_Date("GrA-33017",6190,35);
    };
    Combine("Remicourt_pit_141")
    {
     R_Date("OxA-21409",6139,37);
     R_Date("OxA-21356",6213,36);
     R_Date("OxA-21355",6219,38);
    };
    R_Date("OxA-6688",6205,45);
    R_Date("GrA-33018",6210,35);
    R_Date("GrA-33019",6120,35);
   };
   Boundary("Tansition Blouet 3/4")
   {
   };
   Phase("Blouet 4")
   {
    R_Date("OxA-5878",6065,60);
   };
   Boundary("Tansition Blouet 4/5")
   {
   };
   Phase("Blouet 5")
   {
    R_Date("OxA-5880",6070,60);
    R_Date("OxA-5881",6060,55);
    R_Date("OxA-6691",6105,45);
    R_Date("OxA-5877",6090,90);
```

```
  };
  Boundary("Transition Blouet 5/6")
  {
  };
  Phase("Blouet 6")
  {
   R_Date("OxA-21410",6131,37);
   R_Date("OxA-21412",6183,39);
  };
  Boundary("End Blouet 6")
  {
  };
 };
};
```

**Notes about Model 2**

The number of dates per subphase of the typochronology porposed by Blouet *et al.* (2013) was too low for present purposes. Therefore, only the main phases of this typochronology (ME1-6) have been modelled here.

One radiocarbon date is flagged for having poor agreement with the model by OxCal:

OxA-21412: 6183±39; A=43.3%; 5287-5007 calBC (CI=95.4%). The peaks of the modelled probability distribution fall on valleys of the calibrated range pf the date, and tend towards the younger range of the calibrated range. The date was performed on a seed from a settlement feature at Remicourt (cf. Jadin and Cahen 2003). A residual date cannot be excluded.

## 4. Model 3

This Bayesian chronological model was formulated to check the regional typochronology for the Rhineland (Stehli 1989, cf. Hedges *et al.* 1993) with only those radiocarbon dates from the area and assemblages for which the typochronology was formulated.

### Model code

```
Plot()
 {
  Sequence("Rhineland chronology")
  {
   Boundary("Start Stehli XI");
   Phase("Stehli XI")
   {
    R_Date("OxA-2899",6290,70);
   };
   Span("Duration Stehli XI");
   Boundary("Stehli XI-XII");
   Phase("Stehli XII")
   {
    R_Date("OxA-2897",6230,60);
    R_Date("OxA-2898",6170,60);
    Span("Duration Stehli XII");
   };
   Boundary("Stehli XII-XIII");
   Phase("Stehli XIII")
   {
    R_Date("OxA-2900",6160,60);
    R_Date("OxA-2896",6190,60);
    Span("Duration Stehli XIII");
   };
   Boundary("End Stehli XIII");
  };
 };
```

### Notes about Model 3

The model contains a relatively small number of dates from HG XI-XIII. The coverage of the typochronology is therefore limited.

## 5. Model 4

This Bayesian chronological model was formulated to check the regional typochronology for Limburg from Modderman (1970) with only those radiocarbon dates from the area and assemblages for which the typochronology was formulated.

### Model code

```
Plot()
 {
  Sequence()
  {
   Boundary("Start Modderman 1a");
   Phase("Modderman 1a")
   {
    R_Date("GrA-27837",6170,45);
    R_Date("OxA-15601",6210,38);
    R_Date("GrA-27839",6110,45);
   };
   Boundary("Modderman 1a-1b");
   Phase("Modderman 1b")
   {
    R_Date("OxA-15542",6204,35);
    R_Date("GrA-27836",6240,70);
    R_Date("BRAMS-2611",6154,31);
   };
   Boundary("Modderman 1b-1c");
   Phase("Modderman 1c")
   {
    R_Date("GrA-27838",6260,50);
    Combine("Geleen-Janskamperveld house 13")
    {
     R_Date("GrA-27842",6180,50);
     R_Date("OxA-15600",6208,38);
    };
    R_Date("GrA-52815",6150,35);
   };
   Boundary("Modderman 1c-2b");
   Phase("Modderman 2b")
   {
    R_Date("BRAMS-2602",6201,36);
   };
   Boundary("Modderman 2b-2d");
   Phase("Modderman 2d")
   {
    R_Date("GrN-64062",6035,40);
    R_Date("GrN-64059",6110,40);
   };
   Boundary("End Modderman 2d");
  };
 };
```

### Notes about Model 4

Unfortunately, no radiocarbon dates for phases Id, IIa, IIc, and IIIa in the typochronology from Modderman (1970) could be found. Coverage is therefore limited.

One radiocarbon date is flagged as having a poor agreement index (cf. Bronk Ramsey 1995; 2009a) by OxCal:

GrA-27838: 5331±45BP; A = 55.3%; 5331-5052 calBC (CI=95.4%); attributed to Modderman Ic. The calibrated range of this date is old relative to the modelled age.

The date was performed on a charred seed found in a settlement feature at Geleen-Janskamperveld (Van der Velde 2008). A potential residual date cannot be excluded.

## 6. Model 5

This Bayesian chronological model incorporates simulated dates to determine whether the model structure or shape of the IntCal20 calibration curve gives rise to the issues observed in Model 1.

## Model code

```
Plot()
 {
  Sequence("Chronozones")
  {
   Boundary("Start_RA")
   {
    Start("Start_Start_RA");
    Transition("Duration_Start_RA");
    End("End_Start_RA");
   };
   Phase("RA")
   {
    R_Simulate("RA-0",-5151,43);
    R_Simulate("RA-1",-5150,43);
    R_Simulate("RA-2",-5252,43);
    R_Simulate("RA-3",-5273,43);
    R_Simulate("RA-4",-5196,43);
    R_Simulate("RA-5",-5224,43);
    R_Simulate("RA-6",-5261,43);
    R_Simulate("RA-7",-5293,43);
    R_Simulate("RA-8",-5280,43);
    R_Simulate("RA-9",-5278,43);
    R_Simulate("RA-10",-5146,43);
    R_Simulate("RA-11",-5182,43);
    R_Simulate("RA-12",-5299,43);
    R_Simulate("RA-13",-5264,43);
    R_Simulate("RA-14",-5144,43);
    R_Simulate("RA-15",-5298,43);
    R_Simulate("RA-16",-5188,43);
    R_Simulate("RA-17",-5227,43);
   };
   Boundary("Transition_RA_RM")
   {
    Start("Start_transition_RA_RM");
    Transition("Duration_transition_RA_RM");
    End("End_transition_RA_RM");
   };
   Phase("RM")
   {
    R_Simulate("RM-0",-5124,45);
    R_Simulate("RM-1",-5107,45);
    R_Simulate("RM-2",-5121,45);
    R_Simulate("RM-3",-5136,45);
    R_Simulate("RM-4",-5101,45);
    R_Simulate("RM-5",-5091,45);
    R_Simulate("RM-6",-5084,45);
    R_Simulate("RM-7",-5140,45);
    R_Simulate("RM-8",-5091,45);
    R_Simulate("RM-9",-5113,45);
   };
   Boundary("Transition_RM_RR")
   {
    Start("Start_transition_RM_RR");
    Transition("Duration_transition_RM_RR");
    End("End_transition_RM_RR");
   };
   Phase("RR")
   {
    R_Simulate("RR-0",-5023,53);
```

```
   R_Simulate("RR-1",-5021,53);
   R_Simulate("RR-2",-5020,53);
   R_Simulate("RR-3",-5000,53);
   R_Simulate("RR-4",-5013,53);
   R_Simulate("RR-5",-5065,53);
   R_Simulate("RR-6",-5036,53);
   R_Simulate("RR-7",-5024,53);
   R_Simulate("RR-8",-5002,53);
   R_Simulate("RR-9",-5045,53);
   R_Simulate("RR-10",-5042,53);
   R_Simulate("RR-11",-5013,53);
  };
  Boundary("Transition_RR_RF")
  {
   Start("Start_transition_RR_RF");
   Transition("Duration_transition_RR_RF");
   End("End_transition_RR_RF");
  };
  Phase("RF")
  {
   R_Simulate("RF-0",-5000,60);
   R_Simulate("RF-1",-4993,60);
   R_Simulate("RF-2",-4982,60);
   R_Simulate("RF-3",-4950,60);
   R_Simulate("RF-4",-4961,60);
   R_Simulate("RF-5",-4953,60);
   R_Simulate("RF-6",-4998,60);
   R_Simulate("RF-7",-4975,60);
   R_Simulate("RF-8",-4965,60);
   R_Simulate("RF-9",-4971,60);
   R_Simulate("RF-10",-4992,60);
  };
  Boundary("Transition_RF_RT")
  {
   Start("Start_transition_RF_RT");
   Transition("Duration_transition_RF_RT");
   End("End_transition_RF_RT");
  };
  Phase("RT")
  {
   R_Simulate("RT-0",-4875,40);
   R_Simulate("RT-1",-4928,40);
   R_Simulate("RT-2",-4941,40);
  };
  Boundary("End_RT")
  {
   Start("Start_End_RF");
   Transition("Duration_end_RF");
   End("End_end_RF");
  };
 };
};
```

### Notes about Model 5

This model is a simulation in which the dates are random calendrical dates within the time periods proposed for the chronozones from Blouet *et al.* (2021; calculated on the basis of Meunier 2013; Balkowski 2024a, Fig. 25).

The script for generating the random calendrical dates was written in Python v3.12.4 and is as follows:

```
import csv
from random import randint
```

```
phase_list = [
   ['RA', -5300, -5140, 43, 18],
   ['RM', -5140, -5080, 45, 10],
   ['RR', -5080, -5000, 53, 12],
   ['RF', -5000, -4950, 60, 11],
   ['RT', -4950, -4850, 40, 3],
   ]

simulated_dates = [
   ['Lab_ID', 'BC', '1s']
   ]

for phase in phase_list:
   for i in range(0, phase[-1]):
      year = randint(phase[1], phase[2])
      simulated_dates.append(
         [f'{phase[0]}-{i}', year, phase[3]]
         )

for date in simulated_dates:
   print(date)

filename = 'simulated_dates_again.csv'
with open(filename, 'a+', newline = '') as ef:
   writer = csv.writer(ef, delimiter = ';')
   for date in simulated_dates:
      writer.writerow(date)
```

The model performs well ($C$ > 95%; $A_{model}$=67.5%; $A_{overall}$=70%) despite some simulated dates featuring poor agreement indices. Specifically: RA-4 (A=47.7%), RA-16 (A=52.2%), RR-5 (A=51.8%), RF-0 (A=39.3%), RF-2 (A=46.3%), RF-4 (A=36.2%), RF-9 (A=59.8%). The relatively high number of simulated dates with low agreement for the Rubané final is likely due to the fact that the average error margins of the radiocarbon dates attributed to this period is larger than the proposed duration of said period (see script above). However, this average error margin is also high compared to that found in recent AMS dates in the dataset.

## 7. Model 6

This Bayesian chronological model grants interpretative priority to the overarching typochronology from Blouet *et al.* (2021, Tab. 3) in formulating an absolute chronology for the LBK period in the Rhineland, Hesbaye, and Limburg.

## Model code

```
Plot()
 {
  Sequence("Chronozones impose sequence")
  {
   Outlier_Model("General", T(5), U(0,4), "t");
   Boundary("Start_RA")
   {
    Start("Start_Start_RA");
    Transition("Duration_Start_RA");
    End("End_Start_RA");
   };
   Phase("RA")
   {
    //Assume this date is erroneous
    //R_Date("GrA-27839",6110,45);
    R_Date("BRAMS-1923",6142,33);
    R_Date("BRAMS-2611",6154,31);
    R_Date("GrA-52815",6150,35);
    R_Date("GrA-27837",6170,45);
    R_Date("OxA-15601",6210,38);
    R_Date("OxA-15542",6204,35);
    R_Date("GrA-27836",6240,70);
    Combine("Geleen-Janskamperveld_house_13")
    {
     R_Date("GrA-27842",6180,50);
     R_Date("OxA-15600",6208,38);
    };
    R_Date("GrA-27838",6260,50);
    //Assume this is too old
    R_Date("UtC-13232",6312,35)
    {
     Outlier("General", 1);
    };
    R_Date("UtC-13234",6250,39);
    R_Date("UtC-13235",6229,33);
    //Assume erroneous date
    //R_Date("GrA-53554",6340,50);
    R_Date("GrA-32979",6240,35);
    R_Date("Utc-7179",6230,70);
    Span("Duration_RA");
   };
   Boundary("Transition_RA_RM")
   {
    Start("Start_RA_RM_transition");
    Transition("Duration_RA_RM_transition");
    End("End_RA_RM_transition");
   };
   Phase("RM")
   {
    After("assume residual grain?")
    {
     R_Date("OxA-2899",6290,70);
    };
    Combine("Fexhe_pit_61")
    {
     R_Date("GrA-32977",6200,35);
     R_Date("GrA-33013",6130,35);
    };
    Combine("Fexhe_pit_89")
```

```
 {
  R_Date("GrA-33015",6150,35);
  R_Date("GrA-33017",6190,35);
 };
 R_Date("ECHO-2446.1.1",6150,80);
 Combine("Remicourt_pit_141")
 {
  R_Date("OxA-21409",6139,37);
  R_Date("OxA-21356",6213,36);
  R_Date("OxA-21355",6219,38);
 };
 R_Date("OxA-6688",6205,45);
 Span("Duration_RM");
};
Boundary("Transition_RM_RR")
{
 Start("Start_RM_RR_transition");
 Transition("Duration_RM_RR_transition");
 End("End_RM_RR_transition");
};
Phase("RR")
{
 Before("Assume intrusive cereal?")
 {
  R_Date("OxA-5881",6060,55);
  R_Date("OxA-5878",6065,60);
 };
 R_Date("OxA-2896",6190,60);
 R_Date("OxA-2897",6230,60);
 R_Date("OxA-2898",6170,60);
 R_Date("OxA-2900",6160,60);
 R_Date("BRAMS-2602",6201,36);
 R_Date("OxA-6690",6135,60);
 R_Date("GrA-33019",6120,35);
 R_Date("OxA-6692",6215,45);
 Span("Duration_RR");
};
Boundary("Transition_RR_RF")
{
 Start("Start_RR_RF_transition");
 Transition("Duration_RR_RF_transition");
 End("End_RR_RF_transition");
};
Phase("RF")
{
 After("Assume pit is buggered")
 {
  Combine("Liège_Place Saint Lambert_pit 2")
  {
   R_Date("Lv-1341",6250,80);
   R_Date("Lv-1342",6270,100);
  };
 };
 R_Date("OxA-5880",6070,60);
 R_Date("OxA-6691",6105,45);
 R_Date("OxA-6696",6110,45);
 R_Date("OxA-6697",6105,40);
 R_Date("OxA-6782",6205,60);
 R_Date("OxA-5877",6090,90);
 Before("Assume intrusive cereal")
 {
  R_Date("OxA-5876",6060,55);
  R_Date("GrN-64059",6110,40);
  R_Date("GrN-64062",6035,40);
 };
 Span("Duration_RF");
};
```

```
  Boundary("Transition_RF_RT")
  {
   Start("Start_RF_RT_transition");
   Transition("Duration_RF_RT_transition");
   End("End_RF_RT_transition");
  };
  Phase("RT")
  {
   After("Assume intrusive grain")
   {
    R_Date("KN-1367",6410,45);
   };
   R_Date("OxA-21410",6131,37);
   R_Date("OxA-21411",6108,37);
   Span("Duration_RT");
  };
  Boundary("End_RT")
  {
   Start("Start_End_RT");
   Transition("Duration_End_RT");
   End("End_End_RT");
  };
  //Delete if problems with convergence persist
  Span("Duration_LBK")
 };
};
```

**Notes about Model 6**

OxCal returns suboptimal convergences (cf. Bayliss et al. 2011) for the start boundary of the Rubané ancien (89.4%), the start of this start boundary (91%), the end of this start boundary (93.1%), the duration of the Rubané récent (94.5%), the duration of the Rubané final (94.5%), the end boundary of the Rubané final (94%), the start of this end boundary (94.2%), end of this end boundary (93.4%), and finally the span of the LBK sequence (88.2%).

The low convergences reported above are likely due to the *Span()* queries in Model 6. Other compounding factors are the complexity of the model, the multimodal posterior distributions of the boundaries for the Rubané ancien and final. A version of Model 6 without these queries returns good convergence rates and marginal differences in estimated boundaries, so the estimates reported here are likely robust. Regardless, further work is needed arrive at more precise estimates for these boundaries.

As stated in the Main Text, a number of radiocarbon dates was included with a general outlier model (Bronk Ramsey 2009b), included with the *Before()* or *After()* commands (Bronk Ramsey 2009a), or rejected altogether to maximise the agreement indices of Model 6 over multiple iterations. This applies to the following dates (listed by chronozone).

*Rubané ancien*

Two radiocarbon dates had to be rejected:

- GrA-27839 6110±45BP was performed on a charred seed in the infill of a settlement feature at Geleen-Janskamperveld (Van der Velde 2008).
- GrA-53554 6340±50BP was performed on a charred seed in a post hole at the settlement Stein-Heidekampweg (Porreij-Lyklema and Van Wijk 2012).

UtC-13232 6312±35BP, 5360-5214 calBC (CI=95.4%) could be included with the general outlier model from Bronk Ramsey (2009b). This date was performed on a seed in a settlement feature at Niederkassel-Uckendorf (Heinen 2010).

UtC-13234 6250±39BP, 5312-5066 calBC (CI=95.4%) was flagged as having poor agreement (A= 59.7%). The date was performed on a seed from a settlement feature at Niederkassel-Uckendorf (Heinen 2010). The modelled range of the date is young compared to the unmodelled, calibrated range, likely as the model converges on the 51$^{st}$ century BC for the duration of the Rubané ancien.

*Rubané moyen*
OxA-2899: 6290±70BP, 5470-5048 calBC (CI=95.4%) was performed on grain from a settlement feature at Langweiler 8 (Hedges *et al.* 1993) and has been included as a *terminus post quem*.

*Rubané récent*
Two radiocarbon dates have been included as a *terminus ante quem*.

- OxA-5881: 6060±55BP, 5208-4797 calBC (CI=95.4%) a potential bulk sample of hazelnut shells from a settlement feature at Darion (Jadin and Cahen 2003).
- OxA-5878: 6065±60BP, 5208-4799 calBC (CI=95.4%) a potential bulk sample of grain from Oleye “Al Zèpe” (Jadin and Cahen 2003).

*Rubané final*
The outcomes of a *Combine()* on two dates on bone from an unknown species from the same settlement feature at Liège Place Saint-Lambert (Jadin and Cahen 2003) have been incorporated as a *terminus post quem*. The radiocarbon dates are:

- Lv-1341: 6250±80BP, 5462-4997 calBC (CI=95.4%);
- Lv-1342: 6270±100BP, 5473-4996 calBC (CI=95.4%).

The following dates are treated as a terminus ante quem.

- OxA-5876, 6060±55BP 5208-4797 calBC (CI=95.4%), performed on (potentially bulked) grain, from a settlement feature at Oleye “al Zèpe” (Jadin and Cahen 2003).
- Two dates on charred seeds from Maastricht-Cannerberg (Van Wijk 2016). GrN-64059, 6110±40BP; 5210-4935 calBC (CI=95.4%); GrN-64062, 6035±40BP; 5041-4800 calBC (CI=95.4%).

*Rubané terminal*
KN-1367: 6410±45BP, 5476-5308 calBC (CI=95.4%), performed on a seed from a settlement feature at Lamersdorf-Inden (Jadin and Cahen 2003) is treated as a *terminus post quem*.

## 8. Model 7

This Bayesian chronological model grants interpretative priority to the radiocarbon dates in formulating an absolute chronology for the LBK period in the Rhineland, Hesbaye, and Limburg.

## Model code

```
Plot()
 {
  Outlier_Model("General", T(5), U(0,4), "t");
  Sequence("Rubané ancien")
  {
   Boundary("Start_RA")
   {
    Start("Start_Start_RA");
    Transition("Transition_Start_RA");
    End("End_Start_RA");
   };
   Phase()
   {
    KDE_Plot("RA")
    {
    };
    Sum()
    {
    };
    R_Date("GrA-27839",6110,45)
    {
     Outlier("General", 0.05);
    };
    R_Date("GrA-27837",6170,45)
    {
     Outlier("General", 0.05);
    };
    R_Date("OxA-15601",6210,38)
    {
     Outlier("General", 0.05);
    };
    R_Date("OxA-15542",6204,35)
    {
     Outlier("General", 0.05);
    };
    R_Date("GrA-27836",6240,70)
    {
     Outlier("General", 0.05);
    };
    Combine("Geleen-Janskamperveld_house_13")
    {
     R_Date("GrA-27842",6180,50)
    {
     Outlier("General", 0.05);
    };
     R_Date("OxA-15600",6208,38)
    {
     Outlier("General", 0.05);
    };
    };
    R_Date("GrA-27838",6260,50)
    {
     Outlier("General", 0.05);
    };
    R_Date("BRAMS-1923",6142,33)
    {
     Outlier("General", 0.05);
    };
    R_Date("BRAMS-2611",6154,31)
```

```
 {
  Outlier("General", 0.05);
 };
 R_Date("UtC-13232",6312,35)
 {
  Outlier("General", 0.05);
 };
 R_Date("UtC-13234",6250,39)
 {
  Outlier("General", 0.05);
 };
 R_Date("UtC-13235",6229,33)
 {
  Outlier("General", 0.05);
 };
 R_Date("GrA-53554",6340,50)
 {
  Outlier("General", 0.05);
 };
 R_Date("GrA-52815",6150,35)
 {
  Outlier("General", 0.05);
 };
 R_Date("GrA-32979",6240,35)
 {
  Outlier("General", 0.05);
 };
 R_Date("Utc-7179",6230,70)
 {
  Outlier("General", 0.05);
 };
};
Boundary("End_RA")
{
 Start("Start_End_RA");
 Transition("Transition_End_RA");
 End("End_End_RA");
};
};
Sequence("Rubané moyen")
{
 Boundary("Start_RM")
 {
  Start("Start_Start_RM");
  Transition("Transition_Start_RM");
  End("End_Start_RM");
 };
 Phase()
 {
  KDE_Plot("RM")
  {
  };
  Sum()
  {
  };
  R_Date("OxA-2899",6290,70)
  {
   Outlier("General", 0.05);
  };
  Combine("Fexhe_pit_61")
  {
   R_Date("GrA-32977",6200,35)
  {
   Outlier("General", 0.05);
  };
   R_Date("GrA-33013",6130,35)
  {
```

```
 Outlier("General", 0.05);
};
};
Combine("Fexhe_pit_89")
{
 R_Date("GrA-33015",6150,35)
{
 Outlier("General", 0.05);
};
 R_Date("GrA-33017",6190,35)
{
 Outlier("General", 0.05);
};
};
R_Date("ECHO-2446.1.1",6150,80)
{
 Outlier("General", 0.05);
};
Combine("Remicourt_pit_141")
{
 R_Date("OxA-21409",6139,37)
{
 Outlier("General", 0.05);
};
 R_Date("OxA-21356",6213,36)
{
 Outlier("General", 0.05);
};
 R_Date("OxA-21355",6219,38)
{
 Outlier("General", 0.05);
};
};
R_Date("OxA-6688",6205,45)
{
 Outlier("General", 0.05);
};
};
Boundary("End_RM")
{
 Start("Start_End_RM");
 Transition("Transition_End_RM");
 End("End_End_RM");
};
};
Sequence("Rubané récent")
{
 Boundary("Start_RR")
 {
  Start("Start_Start_RR");
  Transition("Transition_Start_RR");
  End("End_Start_RR");
 };
 Phase()
 {
  KDE_Plot("RR")
  {
  };
  Sum()
  {
  };
  R_Date("OxA-2896",6190,60)
  {
   Outlier("General", 0.05);
  };
  R_Date("OxA-2897",6230,60)
  {
```

```
 Outlier("General", 0.05);
 };
 R_Date("OxA-2898",6170,60)
 {
 Outlier("General", 0.05);
 };
 R_Date("OxA-2900",6160,60)
 {
 Outlier("General", 0.05);
 };
 R_Date("BRAMS-2602",6201,36)
 {
 Outlier("General", 0.05);
 };
 R_Date("OxA-5881",6060,55)
 {
 Outlier("General", 0.05);
 };
 R_Date("OxA-6690",6135,60)
 {
 Outlier("General", 0.05);
 };
 R_Date("GrA-33019",6120,35)
 {
 Outlier("General", 0.05);
 };
 R_Date("OxA-5878",6065,60)
 {
 Outlier("General", 0.05);
 };
 R_Date("OxA-6692",6215,45)
 {
 Outlier("General", 0.05);
 };
};
Boundary("End_RR")
{
 Start("Start_End_RR");
 Transition("Transition_End_RR");
 End("End_End_RR");
};
};
Sequence("Rubané final")
{
 Boundary("Start_RF")
 {
 Start("Start_Start_RF");
 Transition("Transition_Start_RF");
 End("End_Start_RF");
 };
 Phase()
 {
 KDE_Plot("RF")
 {
 };
 Sum()
 {
 };
 R_Date("GrN-64062",6035,40)
 {
 Outlier("General", 0.05);
 };
 R_Date("GrN-64059",6110,40)
 {
 Outlier("General", 0.05);
 };
 R_Date("OxA-5880",6070,60)
```

```
 {
  Outlier("General", 0.05);
 };
 R_Date("OxA-6691",6105,45)
 {
  Outlier("General", 0.05);
 };
 R_Date("OxA-6696",6110,45)
 {
  Outlier("General", 0.05);
 };
 R_Date("OxA-6697",6105,40)
 {
  Outlier("General", 0.05);
 };
 R_Date("OxA-6782",6205,60)
 {
  Outlier("General", 0.05);
 };
 Combine("Liège_Place Saint Lambert_pit 2")
 {
  R_Date("Lv-1341",6250,80)
  {
   Outlier("General", 0.05);
  };
  R_Date("Lv-1342",6270,100)
  {
   Outlier("General", 0.05);
  };
 };
 R_Date("OxA-5876",6060,55)
 {
  Outlier("General", 0.05);
 };
 R_Date("OxA-5877",6090,90)
 {
  Outlier("General", 0.05);
 };
};
Boundary("End_RF")
{
 Start("Start_End_RF");
 Transition("Transition_End_RF");
 End("End_End_RF");
};
};
Sequence("Rubané terminal")
{
 Boundary("Start_RT")
 {
  Start("Start_Start_RT");
  Transition("Transition_Start_RT");
  End("End_Start_RT");
 };
 Phase()
 {
  KDE_Plot("RT")
  {
  };
  Sum()
  {
  };
  R_Date("KN-1367",6410,45)
  {
   Outlier("General", 0.05);
  };
  R_Date("OxA-21410",6131,37)
```

```
   {
    Outlier("General", 0.05);
   };
   R_Date("OxA-21411",6108,37)
   {
    Outlier("General", 0.05);
   };
  };
  Boundary("End_RT")
  {
   Start("Start_End_RT");
   Transition("Transition_End_RT");
   End("End_End_RT");
  };
 };
 Order("Phase order")
 {
  Date("=Start_RA");
  Date("=End_RA");
  Date("=Start_RM");
  Date("=End_RM");
  Date("=Start_RR");
  Date("=End_RR");
  Date("=Start_RF");
  Date("=End_RF");
  Date("=Start_RT");
  Date("=End_RT");
 };
};
```

**Notes about Model 7**

Initial versions of Model 7 returned poor convergence for some boundaries, likely due to combination of a complex model structure and sparse radiocarbon dates for some phases. To compensate for this issue, the general outlier model from Bronk Ramsey (2009b) was applied to all dates with initial odds of 0.05. These odds were incremented as necessary over multiple iterations of the model.

OxCal flags one radiocarbon date as an outlier: OxA-5881 (6060±55BP, A=59.9%, 5208-4797 calBC (CI=95.4%)). This date is attributed to the Rubané récent and its calibrated range is young relative to its modelled range. This date was performed on charred hazelnut shells (potentially a bulk sample) from a settlement feature at Darion (Jadin and Cahen 2003). This may be an intrusive sample.

## 9. Model 8

This Bayesian chronological model was formulated to investigate settlement dynamics during the LBK and post-LBK period in the Rhineland.

## Model code

```
Plot()
 {
  Outlier_Model("General", T(5), U(0,4), "t");
  Sequence("Rhineland LBK")
  {
   Boundary("Start_LBK")
   {
    Start("Start_Start_LBK");
    Transition("Transition_Start_LBK");
    End("End_Start_LBK");
   };
   Phase("Lamersdorf-Inden")
   {
    R_Date("KN-1367",6410,45)
    {
     Outlier("General", 1);
    };
   };
   Phase("Langweiler 9")
   {
    R_Date("OxA-2901",6250,60);
   };
   Sequence("Langweiler 2_Early")
   {
    R_Date("OxA-2897",6230,60);
   };
   Phase("Langweiler 8_houses")
   {
    R_Date("OxA-2899",6290,70);
   };
   Sequence("Niederkassel-Uckendorf")
   {
    Phase("Earliest_phase")
    {
     R_Date("UtC-13232",6312,35)
     {
      Outlier("General", 0.05);
     };
    };
    Phase("Main phase")
    {
     R_Date("UtC-13234",6250,39);
     R_Date("UtC-13235",6229,33);
    };
   };
   Phase(Frimmersdorf 122)
   {
    R_Date("UtC-7179",6230,70);
   };
   Phase("Königshoven")
   {
    After("Residual sherd")
    {
     R_Date("BRAMS-2029",6276,24);
    };
    R_Date("BRAMS-2026",6123,27);
   };
   Phase("Müddersheim")
   {
    R_Date("MAMS-37745",6195,24);
```

```
 };
 Phase("Younger LBK?")
 {
  R_Date("MAMS-37747",6077,25);
  R_Date("OxA-2900",6160,60);
  R_Date("OxA-2898",6170,60);
  R_Date("OxA-2896",6190,60);
 };
 Span("Duration_Rhineland_LBK");
 Boundary("End_LBK")
 {
  Start("Start_End_LBK");
  Transition("Transition_End_LBK");
  End("End_End_LBK");
 };
};
Sequence(Rhineland post-LBK)
{
 Boundary("Start_post-LBK")
 {
  Start("Start_Start_post-LBK");
  Transition("Transition_Start_post-LBK");
  End("End_Start_post-LBK");
 };
 Phase()
 {
  R_Date("MAMS-37743",5461,27);
  R_Date("MAMS-37744",5527,24);
 };
 Span("Duration_Rhineland_post-LBK");
 Boundary("End_post-LBK")
 {
  Start("Start_End_post-LBK");
  Transition("Transition_End_post-LBK");
  End("End_End_post-LBK");
 };
};
Order()
{
 Date("=Start_LBK");
 Date("=End_LBK");
 Date("=Start_post-LBK");
 Date("=End_post-LBK");
};
Difference("Overlap_LBK_post-LBK", "End_End_LBK", "Start_Start_post-LBK");
};
```

### Notes about Model 8

OxCal returns poor convergence (cf. Bayliss et al. 2011) for the start boundary (C=7%), dates, and end boundary (C=12.6%) of the post-LBK groups in Model 8. This is likely due to the combination of sparse radiocarbon dates and multimodal posterior distributions. This part of Model 8 should be ignored until further radiocarbon dates become available and the model can be reworked.

## 10. Model 9

This Bayesian chronological model was formulated to investigate settlement dynamics during the LBK and post-LBK period in Limburg.

## Model code

```
Plot()
 {
  Options()
  {
   ConvergenceData = TRUE;
  };
  Outlier_Model("General", T(5), U(0,4), "t");
  Outlier_Model("Cremation", Exp(0.9,-10,-0.1), U(1,3),"t");
  Sequence("Limburg_LBK")
  {
   Boundary("Start_LBK")
   {
    Start("Start_Start_LBK");
    Transition("Transition_Start_LBK");
    End("End_Start_LBK");
   };
   Phase("Elsloo-Koolweg_cemetery")
   {
    After("Charcoal from cremation burial")
    {
     R_Date("GrN-5733",6330,75);
    };
    R_Date("GrM-25653",6215,30)
    {
     Outlier("Cremation", 1);
    };
    R_Date("GrM-25657",6185,30)
    {
     Outlier("Cremation", 1);
    };
    R_Date("GrM-25654",6210,30)
    {
     Outlier("Cremation", 1);
    };
    R_Date("GrM-25652",6197,29)
    {
     Outlier("Cremation", 1);
    };
   };
   Phase("Geleen-Janskamperveld")
   {
    R_Date("GrA-27837",6170,45)
    {
     Outlier("General", 0.05);
    };
    Combine("feature 32100")
    {
     R_Date("OxA-15601",6210,38);
     R_Date("GrA-27839",6110,45);
    };
    R_Date("OxA-15542",6204,35)
    {
     Outlier("General", 0.05);
    };
    R_Date("GrA-27836",6240,70)
    {
     Outlier("General", 0.05);
    };
    Combine("feature 31075")
    {
```

```
  R_Date("GrA-27842",6180,50)
  {
   Outlier("General", 0.05);
  };
  R_Date("OxA-15600",6208,38)
  {
   Outlier("General", 0.05);
  };
 };
 R_Date("GrA-27838",6260,50)
 {
  Outlier("General", 1);
 };
 R_Date("BRAMS-1923",6142,33)
 {
  Outlier("General", 0.05);
 };
 R_Date("BRAMS-2611",6154,31)
 {
  Outlier("General", 0.05);
 };
};
Phase("Maastricht-Klinkers")
{
 R_Date("BRAMS-2602",6201,36);
};
Phase("Stein-Heidekampweg")
{
 After(Grain in post hole)
 {
  R_Date("GrA-53554",6430,50);
 };
 R_Date("GrA-52815",6150,35);
};
Phase("Maastricht-Cannerberg")
{
 Before("Intrusive grain?")
 {
  R_Date("GrN-64062",6035,40);
 };
 R_Date("GrN-64059",6110,40);
};
Span(Dutation_Limburg_LBK);
Boundary("End_LBK")
{
 Start("Start_End_LBK");
 Transition("Transition_End_LBK");
 End("End_End_LBK");
};
};
Sequence("Dutch Post-LBK")
{
 Boundary("Start_SW")
 {
  Start("Start_Start_SW");
  Transition("Transition_Start_SW");
  End("End_Start_SW");
 };
 Phase()
 {
  KDE_Plot("SW")
  {
  };
  Sum()
  {
  };
  R_Date("GrA-21376",5820,50)
```

```
{
 Outlier("General", 0.05);
};
R_Date("GrA-64342",5380,40)
{
 Outlier("General", 0.05);
};
R_Date("GrA-62951",5610,40)
{
 Outlier("General", 0.05);
};
R_Date("GrA-13278",5730,50)
{
 Outlier("General", 0.05);
};
R_Date("GrA-13296",6050,50)
{
 Outlier("General", 0.05);
};
R_Date("GrA-10950",5430,60)
{
 Outlier("General", 0.05);
};
R_Date("GrA-13275",6420,50)
{
 Outlier("General", 0.05);
};
R_Date("GrA-15034",6010,55)
{
 Outlier("General", 0.05);
};
R_Date("GrA-13272",5900,50)
{
 Outlier("General", 0.05);
};
R_Date("GrM-22781",5569,27)
{
 Outlier("General", 0.05);
};
R_Date("GrM-23702",5500,45)
{
 Outlier("General", 0.05);
};
R_Date("GrM-22775",5514,29)
{
 Outlier("General", 0.05);
};
R_Date("GrM-25038",5530,30)
{
 Outlier("General", 0.05);
};
R_Date("GrM-22851",6319,29)
{
 Outlier("General", 0.05);
};
R_Date("GrM-22778",6425,50)
{
 Outlier("General", 0.05);
};
R_Date("GrM-25040",6126,29)
{
 Outlier("General", 0.05);
};
R_Date("GrM-25043",6198,30)
{
 Outlier("General", 0.05);
};
```

```
R_Date("GrM-22776",6019,29)
{
 Outlier("General", 0.05);
};
R_Date("GrM-26625",6080,27)
{
 Outlier("General", 0.05);
};
R_Date("GrM-26624",6047,27)
{
 Outlier("General", 0.05);
};
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{
 Outlier("Cremation", 1);
};
R_Date("KIA-17997",5550,35)
{
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};
R_Date("KIA-17987",5570,30)
{
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};
R_Date("RICH-26555",5499,44)
{
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};
R_Date("RICH-26867",5549,69)
{
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};
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{
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};
R_Date("RICH-26871",5364,30)
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};
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{
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};
R_Date("RICH-26868",5192,46)
{
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};
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{
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};
R_Date("GrN-8240",5330,35)
{
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};
R_Date("GrN-8241",5385,45)
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R_Date("GrM-25036",6017,29)
{
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```

```
};
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{
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};
R_Date("GrM-25035",6492,29)
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};
R_Date("GrM-25033",6502,30)
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};
R_Date("GrM-26626",6167,29)
{
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};
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{
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};
R_Date("GrM-22772",6298,29)
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};
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};
R_Date("GrM-22769",6473,29)
{
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};
R_Date("GrM-25044",5905,29)
{
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};
R_Date("GrM-25037",6223,29)
{
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};
R_Date("GrA-9802",6050,50)
{
 Outlier("General", 0.05);
};
R_Date("GrA-9799",6540,50)
{
 Outlier("General", 0.05);
};
R_Date("GrA-9798",6320,50)
{
 Outlier("General", 0.05);
};
R_Date("GrA-9803",6380,50)
{
 Outlier("General", 0.05);
};
R_Date("OxA-15608",5267,35)
{
 Outlier("General", 0.05);
};
R_Date("OxA-15612",5269,37)
{
```

```
 Outlier("General", 0.05);
};
R_Date("OxA-15610",5278,36)
{
 Outlier("General", 0.05);
};
R_Date("OxA-15609",5334,35)
{
 Outlier("General", 0.05);
};
R_Date("OxA-15611",5358,34)
{
 Outlier("General", 0.05);
};
R_Date("GrM-27308",5247,26)
{
 Outlier("General", 0.05);
};
R_Date("GrM-27306",5272,28)
{
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};
R_Date("GrM-27300",5213,26)
{
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};
R_Date("GrM-27298",5300,26)
{
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};
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{
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};
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{
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};
R_Date("GrM-27304",5326,26)
{
 Outlier("General", 0.05);
};
R_Date("GrM-27305",5297,26)
{
 Outlier("General", 0.05);
};
R_Date("GrA-35308",5290,40)
{
 Outlier("General", 0.05);
};
R_Date("GrA-34814",5245,40)
{
 Outlier("General", 0.05);
};
R_Date("GrA-38187",5340,45)
{
 Outlier("General", 0.05);
};
R_Date("GrA-38188",5230,40)
{
 Outlier("General", 0.05);
};
R_Date("GrA-38189",5340,45)
{
 Outlier("General", 0.05);
};
R_Date("GrN-30447",5390,70)
```

```
{
 Outlier("General", 0.05);
};
R_Date("GrA-33953",5010,40)
{
 Outlier("General", 0.05);
};
R_Date("GrA-33954",5350,45)
{
 Outlier("General", 0.05);
};
R_Date("GrM-28833",5330,30)
{
 Outlier("General", 0.05);
};
R_Date("GrM-28294",5317,24)
{
 Outlier("General", 0.05);
};
R_Date("GrM-28800",5380,27)
{
 Outlier("General", 0.05);
};
R_Date("GrM-28801",5387,27)
{
 Outlier("General", 0.05);
};
R_Date("GrM-28802",5366,27)
{
 Outlier("General", 0.05);
};
R_Date("GrM-28295",5338,16)
{
 Outlier("General", 0.05);
};
R_Date("GrM-28831",5365,30)
{
 Outlier("General", 0.05);
};
R_Date("GrM-28832",5350,30)
{
 Outlier("General", 0.05);
};
R_Date("GrM-29664",5321,27)
{
 Outlier("General", 0.05);
};
R_Date("GrM-29665",5327,29)
{
 Outlier("General", 0.05);
};
R_Date("GrM-29661",5332,27)
{
 Outlier("General", 0.05);
};
R_Date("GrM-29659",5306,27)
{
 Outlier("General", 0.05);
};
R_Date("GrM-29667",5307,27)
{
 Outlier("General", 0.05);
};
R_Date("GrM-28799",5348,27)
{
 Outlier("General", 0.05);
};
```

```
R_Date("GrM-28292",5348,27)
{
 Outlier("General", 0.05);
};
R_Date("GrM-28293",5349,27)
{
 Outlier("General", 0.05);
};
R_Date("GrN-26215",4850,50)
{
 Outlier("General", 0.05);
};
R_Date("GrN-26214",4980,70)
{
 Outlier("General", 0.05);
};
R_Date("GrN-26216",4740,50)
{
 Outlier("General", 0.05);
};
R_Date("GrN-26217",4710,60)
{
 Outlier("General", 0.05);
};
R_Date("GrN-26218",4560,60)
{
 Outlier("General", 0.05);
};
R_Date("GrN-26219",4480,70)
{
 Outlier("General", 0.05);
};
R_Date("GrN-14122",5035,35)
{
 Outlier("General", 0.05);
};
R_Date("KIA-32618",5595,35)
{
 Outlier("General", 0.05);
};
R_Date("RICH-24227",5586,38)
{
 Outlier("General", 0.05);
};
R_Date("RICH-27829",5558,31)
{
 Outlier("General", 0.05);
};
R_Date("RICH-27830",5493,30)
{
 Outlier("General", 0.05);
};
R_Date("KIA-17986",5400,30)
{
 Outlier("General", 0.05);
};
R_Date("RICH-24755",5370,35)
{
 Outlier("General", 0.05);
};
R_Date("NZA-12076",5220,55)
{
 Outlier("General", 0.05);
};
R_Date("KIA-35804",5570,35)
{
 Outlier("General", 0.05);
```

```
  };
  R_Date("KIA-35771",5490,40)
  {
   Outlier("General", 0.05);
  };
  R_Date("KIA-36257",5385,30)
  {
   Outlier("General", 0.05);
  };
  R_Date("KIA-35769",5350,40)
  {
   Outlier("General", 0.05);
  };
  R_Date("KIA-35772",5325,35)
  {
   Outlier("General", 0.05);
  };
  R_Date("KIA-36231",5305,50)
  {
   Outlier("General", 0.05);
  };
  R_Date("KIA-35786",5280,40)
  {
   Outlier("General", 0.05);
  };
 };
 Span("Duration_SW");
 Boundary("End_SW")
 {
  Start("Start_End_SW");
  Transition("Transition_End_SW");
  End("End_End_SW");
 };
};
Order()
{
 Date("=Start_LBK");
 Date("=End_LBK");
 Date("=Start_SW");
 Date("=End_SW");
};
Difference("Overlap_LBK_SW", "End_End_LBK", "Start_Start_SW");
};
```

**Notes about Model 9**

Initial iterations of this model suffered from poor convergence for some dates and the boundaries. Two steps were taken to address this issue.

Firstly, the general outlier model from Bronk Ramsey (2009b) and (where appropriate) cremation outlier model from Rose *et al.* (2020) were applied. Odds of an outlier were set to 0.05 initially, except for cremations which were set to 1. These odds were incremented as needed over multiple iterations of Model 9.

Secondly, dates which continued to be flagged for poor agreement were incorporated as *terminus post quem* or *terminus ante quem.* These dates are:

- GrA-53554: 6340±50BP; A=31.1%; 5479-5312 calBC (CI=95.4%). This date was performed on a charred seed from a post hole at Stein-Hedekampweg (Porreij-Lyklema and Van Wijk 2012). The date is incorporated as a *terminus post quem* for this settlement.
- GrN-64062: 6035±40BP; A=10.5%; 5041-4800 calBC (CI=95.4%). The date was performed on charred seeds from a settlement feature at Maastricht-

Cannerberg (Van Wijk 2016). This date was flagged as too young relative to the modelled age of the settlement and had to be incorporated as a *terminus ante quem.*

In addition, a date from outside the high-quality dataset was incorporated as a *terminus post quem* to stabilise the modelled dates from the LBK cemetery at Elsloo-Koolweg. The date is: GrN-5733, 6330±75BP and was performed on charred twigs associated with a cremation burial (Vogel and Waterbolk 1963, Lanting and Van der Plicht 2000).

Despite these efforts, OxCal flags three dates for having poor agreement. These are listed by archaeological phenomenon below.

*LBK*
GrA-27839: 6110±45; A=58.7%; 5210-4906 calBC (CI=95.4%). The radiocarbon date was performed on a charred seed from a settlement context Geleen-Janskamperveld (Van der Velde 2008), but the modelled range of the settlement coincides with a trough in the calibrated range of the date.

*SWB*
Two dates performed on peat layers from the settlement at Wetsingermaar (Menne and Brunner 2021, Supplement 1; Raemaekers et al. 2012) are flagged. The modelled ranges of these dates are old compared to their calibrated ranges. Potentially an offset due to the natural growth process of peat (cf. Quik *et al.* 2022).

- GrA-26218: 4560±60BP; A=7.6%; 3509-3033 calBC (CI=95.4%).
- GrN-26219: 4480±70BP; A=5.6%; 3364-2929 calBC (CI=95.4%).

OxCal does not return an estimate for the end of the *Boundary()* at the end of the SWB sequence in Model 9. However, the end of the end boundary suggests an end date between 3600-3400 BC.

## 11. Model 10

This Bayesian chronological model was formulated to investigate settlement dynamics during the LBK and post-LBK period in Hesbaye.

## Model code

```
Plot()
 {
  Sequence("Hesbaye LBK")
  {
   Boundary("Start_LBK")
   {
    Start("Start_Start_LBK");
    Transition("Transition_Start_LBK");
    End("End_Start_LBK");
   };
   Phase("Pioneer_phase")
   {
    Phase("Darion_pioneer")
    {
     R_Date("OxA-6782",6205,60);
    };
    Phase("Hollogne-Douze Bonniers")
    {
     R_Date("OxA-6692",6215,45);
    };
    Phase("Fexhe_pioneer")
    {
     Combine("Pit 61")
     {
      R_Date("GrA-32977",6200,35);
      R_Date("GrA-33013",6130,35);
     };
     Combine("Pit 89")
     {
      R_Date("GrA-33015",6150,35);
      R_Date("GrA-33017",6190,35);
     };
     R_Date("GrA-32979",6240,35);
    };
    Phase("Liège-Place Saint Lambert_pioneer")
    {
     Combine("Liège-Place Saint Lambert Pit 2")
     {
      R_Date("Lv-1341",6250,80);
      R_Date("Lv-1342",6270,100);
     };
    };
    Phase("Oleye-Al Zèpe_pioneer")
    {
     R_Date("OxA-5877",6090,90);
    };
    Phase("Remicourt_pioneer")
    {
     Combine("House 1")
     {
      R_Date("OxA-21409",6139,37);
      R_Date("OxA-21356",6213,36);
      R_Date("OxA-21355",6219,38);
     };
    };
    Phase("Waremme-Vinâve_pioneer")
    {
     R_Date("OxA-6688",6205,45);
    };
    Phase("Vaux-et-Borset")
```

```
 {
  R_Date("OxA-6906",6195,50);
 };
};
Boundary("End Pioneer-Start Main")
{
};
Phase("Main occupation")
{
 Phase("Darion_main")
 {
  R_Date("OxA-5879",6060,55);
  R_Date("OxA-5880",6070,60);
  R_Date("OxA-5881",6060,55)
  R_Date("OxA-6689",6070,60);
  R_Date("OxA-6690",6135,60);
  R_Date("OxA-6691",6105,45);
  R_Date("OxA-6696",6110,45);
  R_Date("OxA-6697",6105,40);
 };
 Phase("Fexhe_main")
 {
  After("Residual grain Fexhe")
  {
   R_Date("GrA-33018",6210,35);
  };
  R_Date("GrA-33019",6120,35);
 };
 Phase("Momalle_main")
 {
  R_Date("ECHO-2446.1.1",6150,80);
 };
 Phase("Oleye-Al_Zèpe_main")
 {
  R_Date("OxA-5876",6060,55);
  R_Date("OxA-5878",6065,60);
 };
 Phase("Remicourt_main")
 {
  After("Residual grain Remicourt")
  {
   R_Date("OxA-21412",6183,39);
  };
  R_Date("OxA-21411",6108,37);
  R_Date("OxA-21410",6131,37);
 };
};
Span("Duration_Hesbaye_LBK");
Boundary("End_LBK")
{
 Start("Start_End_LBK");
 Transition("Transition_End_LBK");
 End("End_End_LBK");
};
};
Sequence("Hesbaye post-LBK")
{
 Boundary("Start_BQVSG")
 {
  Start("Start_Start_BQVSG");
  Transition("Transition_Start_BQVSG");
  End("End_Start_BQVSG");
 };
 Phase("Vaux-et-Borset_BQVSG")
 {
  After("residual grain")
  {
```

```
    R_Date("OxA-6905",6200,55);
   };
   R_Date("OxA-6904",6040,45);
  };
  Phase("Darion_ BQY")
  {
   R_Date("OxA-6958",6045,65);
  };
  Span("Duration_BQVSG");
  Boundary("End_BQVSG")
  {
   Start("Start_End_BQVSG");
   Transition("Transition_End_BQVSG");
   End("End_End_BQVSG");
  };
 };
 Order()
 {
  Date("=Start_LBK");
  Date("=End_LBK");
  Date("=Start_BQVSG");
  Date("=End_BQVSG");
 };
 Difference("Overlap LBK_BQVSG", "End_End_LBK", "Start_Start_BQVSG");
};
```

**Notes about Model 10**

An intitial version of Model 10 in which the dates were grouped by settlement did not yield stable outcomes. Over multiple iterations with alternative configurations, the best solution turned out to involve grouping the dates into a ‘pioneer’ and ‘main’ phase, following the distinction in Bosquet and Golitko (2012).

Two dates associated with LBK contexts were treated as terminus post quem (cf. Bosquet and Golitko 2012):

- GrA-33018 6210±35BP, 5300-5046 calBC (CI=95.4%). This date was performed on a cereal or a bulk sample of cereals from a settlement feature at Fexhe.
- OxA-21412, 6183±39BP, 5287-5007calBC (CI=95.4%). This date was also performed on a cereal from a settlement feature, but from the LBK settlement at Remicourt.

One radiocarbon date associated with BQVSG material from Vaux-et-Borset was included as a terminus post quem for this site, following the comments from I. Jadin in Bronk Ramsey *et al.* (2000, 251-2). The date is OxA-6905 (6200±55BP, 5304-5002 calBC, CI=95.4%) and was performed on a charred hazelnut shell.

## 12. Bibliography

*Amkreutz, L. W. S. W. 2013*: Persistent Traditions: A Long-Term Perspective on Communities in the Process of Neolithisation in the Lower Rhine Area (5500-2500 cal BC), Leiden: Sidestone Press.

*Bakels, C. C. 1992*: The botanical shadow of two early Neolithic settlements in Belgium: Carbonized seeds and disturbances in the pollen record. Review of Palaeobotany 73, 1–4, 1–19.

*Bakels, C. C. – Van Beurden, L. – Vernimmen, T. 2001*: Archeobotanie. In: L. P. Louwe Kooijmans ed., Archeologie in de Betuweroute: Hardinxveld-Giessendam De Bruin, een kampplaats uit het Laat-Mesolithicum en het begin van de Swifterbant-cultuur (5500-4450 v. Chr.), Amersfoort: Rijksdienst voor Oudheidkundig Bodemonderzoek (Rapportage Archaeologische Monumentenzorg 88), 369–493.

*Balkowski, N. 2024a*: Chronologie und Siedlungsstruktur des Fundplatzes. In: N. Balkowski & R. Peters eds., Der bandkeramische Fundplatz Arnoldsweiler-Ellebach (Band 1), Bonn: LVR-Amt für Bodendenkmalpflege im Rheinland (Rheinische Ausgrabungen 85/1), 43–135.

*Balkowski, N. 2024b*: Siedlung. In: N. Balkowski & R. Peters eds., De bandkeramische Fundplatz Arnoldsweiler-Ellebach (Band 1), Bonn: LVR-Amt für Bodendenkmalpflege im Rheinland (Rheinische Ausgrabungen 85/1), 137–289.

*Balkowski, N. – Classen, E. – Peters, R. 2016*: The older LBK site of Niederkassel-Uckendorf revisited. In: T. Kerig, K. Nowak, & G. Roth eds., Alles was zählt...: Festschrift für Andreas Zimmermann, Bonn: Verlag Rudolf Habelt GmbH, 79–92.

*Bayliss, A. 2015*: Quality in Bayesian chronological models in archaeology. World Archaeology 47, 4, 677–700. doi: 10.1080/00438243.2015.1067640.

*Bayliss, A. – Van der Plicht, J. – Bronk Ramsey, C. – McCormac, G. – Healy, F. – Whittle, A. 2011*: Towards generational time-scales: the quantitative interpretation of archaeological chronologies. In: A. Whittle, F. Healy, & A. Bayliss eds., Gathering time: Dating the Early Neolithic enclosure of Southern Britain and Ireland, Oxford: Oxbow Books, 17–59.

*Blouet, V. – Bosquet, D. – Constantin, C. – Fock, H. – Ilett, M. – Jadin, I. – Klag, T. – Petitdidier, M.-P. – Thomashausen, L. 2021*: Le Rubané en Belgique: nouvelle chronologie céramique et synchronisation avec les régions voisines. Bulletin de la Société préhistorique française 118, 2, 277–322.

*Blouet, V. – Klag, T. – Petitdidier, M.-P. – Thomashausen, L. 2013*: Le Néolithique ancien en Lorraine: Inventaire des sites et planches céramique, Paris: La Société Préhistorique Française (Mémoire LV).

*Boelicke, U. 1988a*: Die Gruben. In: U. Boelicke, D. Von Brandt, J. Lüning, P. Stehli, & A. Zimmerman eds., Die bandkeramische Siedlundsplatz Langweiler 8, Gemeinde Aldenhoven, Kreis Düren: Beiträge zur neolithische Besiedlung der Aldenhover

Platte III 1, Bonn: Rheinland-Verlag GmbH (Rheinische Ausgrabungen 28/1), 300–94.

*Boelicke, U. 1988b*: Das Erdwerk. In: Ulrich Boelicke, D. Von Brandt, J. Lüning, P. Stehli, & A. Zimmermann eds., Die bandkeramische Siedlundsplatz Langweiler 8, Gemeinde Aldenhoven, Kreis Düren: Beiträge zur neolithische Besiedlung der Aldenhover Platte III 1, Köln: Rheinland-Verlag, 395–428.

*Boudin, M. – Van Strydonck, M. – Crombé, P. 2009*: Radiocarbon Dating of Pottery Food Crusts: Reservoir Effect or not? The case of the Swifterbant pottery from Doel "Deurganckdok". In: P. Crombé, M. Van Strydonck, M. Boudin, J. Sergant, & M. Bats eds., Chronology and Evolution within the Mesolithic of North-West Europe, Newcastle upon Tyne: Cambridge Scholars Publishing, 727–45.

*Boudin, M. – Strydonck, M. Van – Crombé, P. – Clercq, W. De – van Dierendonck, R. M. – Jongepier, H. – Ervynck, A. – Lentacker, A. 2010*: Fish Reservoir Effect on Charred Food Residue $^{14}$C Dates: Are Stable Isotope Analyses the Solution? Radiocarbon 52, 2, 697–705. doi: 10.1017/S0033822200045719.

*Bosquet, D. – Fock, H. – Goffioul, C. – Marchal, J.-P. – Preud'homme, D. 2004*: La néolithisation en Hesbaye (Belgique): apports des fouilles récentes (1996-1999) sur le tracé oriental du TGV et le site de Ans, à Alleur. In: I. Jadin & A. Hauzeur eds., Le Néolithique au Proche Orient et en Europe, Oxford: Oxbow Books (BAR International Series 1303), 81–94.

*Bosquet, D. – Golitko, M. 2012*: Highlighting and characterising the pioneer phase of the Hesbayen Linear Pottery Culture (Liège province, Belgium). In: R. Smolnik, S. Wolfram, & H. Stäuble eds., Siedlungsstruktur und Kulturwandel in der Bandkeramik: Beiträge der internationalen Tagung "Neue Fragen zur Bandkeramik oder alles beim Alten?!"; Leipzig, 23 bis 24. September 2010, Dresden: Landesamt für Archäologie (Arbeits- und Forschungsberichte zur sächsischen Bodendenkmalpflege 25), 91–106.

*Breunig, P. 1985*: Bandkeramische Phasen und 14C-Datierung: Ein Vergleich. Archaeologischen Korrespondenzblatt 15, 139–45.

*Breunig, P. 1987*: 14C-Chronologie des Vorderasiatischen, Südost- und Mitteleuropäischen Neolithikums, Köln: Böhlau Verlag.

*Bronk Ramsey, C. 1995*: Radiocarbon calibration and analysis of stratigraphy: The OxCal program. Radiocarbon 37, 2, 425–430. doi: 10.1017/S0033822200030903.

*Bronk Ramsey, C. 2009a*: Bayesian analysis of radiocarbon dates. Radiocarbon 51, 1, 337–60.

*Bronk Ramsey, C. 2009b*: Dealing with outliers and offsets in radiocarbon dating. Radiocarbon 51, 3, 1023–1045. doi: 10.1017/S0033822200034093.

*Bronk Ramsey, C. 2021*: OxCal v4.4.4.

*Bronk Ramsey, C. – Pettitt, P. B. – Hedges, R. E. M. – Hodgins, G. W. L. – Owen, D. C. 2000*: Radiocarbon dates from the Oxford AMS system: Archaeometry datelist 29. Archaeometry 42, 1, 243–254. doi: 10.1111/j.1475-4754.2000.tb00880.x.

*Burnez-Lanotte, L. – Caspar, J.-P. – Constantin, C. 2001*: Rapports chronologiques et culturels entre Rubané et Groupe de Blicquy à Vaux-et-Borset (Hesbaye, Belgique). Bulletin de la Société préhistorique française 98, 1, 53–76. doi: 10.3406/bspf.2001.12439.

*Çakirlar, C. – Breider, R. – Koolstra, F. – Cohen, K. M. – Raemaekers, D. C. M. 2020*: Dealing with domestic animals in the fith millennium cal BC Dutch wetlands:new insights from old Swifterbant assemblages. In: K. J. Gron, L. Sørensen, & P. Rowly-Conwy eds., Farmers at the frontier: A pan-European perspective on neolithisation, Oxford: Oxbow Books, 263–87.

*Casanova, E. – Knowles, T. D. J. – Bayliss, A. – Roffet-Salque, M. – Heyd, V. – Pyzel, J. – Claßen, E. – Domboróczki, L. – Ilett, M. – Lefranc, P. – Jeunesse, C. – Marciniak, A. – van Wijk, I. – Evershed, R. P. 2022*: Dating the emergence of dairying by the first farmers of Central Europe using 14C analysis of fatty acids preserved in pottery vessels. Proceedings of the National Academy of Sciences 119, 43. doi: 10.1073/pnas.2109325118.

*Claßen, E. 1998*: Der linearbandkeramische Siedlungsplatz Frimmersdorf 122, Erftkreis, Universität zu Köln.

*Craig, O. 2004*: Organic analysis of ‘food crusts’ from sites in the Schelde valley, Belgium: a preliminary evaluation. Notae Praehistoricae 24, 209–17.

*Crombé, P. – Boudin, M. – Van Strydonck, M. 2008*: Swifterbant pottery in the Scheldt Basin and the emergence of the earliest indigenous pottery in the sandy lowlands of Belgium. In: S. Hartz, F. Lüth, & T. Terberger eds., Early pottery in the Baltic: Dating, origin, and social context, Köln: Römisch-Germanischen Kommission (Bericht der Römisch-Germanischen Kommission 89), 465–83.

*Cziesla, E. – Ibeling, T. 2014*: Anhang: AMS-Datierungen. In: E. Cziesla & T. Ibeling eds., Autobahn 4. Fundplatz der Extraklasse: Archäeologie unter den neuen Bundesautobahn bei Arnoldsweiler, Langenweissenbach: Beier & Beran, 304–5.

*Dee, M. W. – Palstra, S. W. L. – Aerts-Bijma, A. T. – Bleeker, M. O. – de Bruijn, S. – Ghebru, F. – Jansen, H. G. – Kuitems, M. – Paul, D. – Richie, R. R. – Spriensma, J. J. – Scifo, A. – van Zonneveld, D. – Verstappen-Dumoulin, B. M. A. A. – Wietzes-Land, P. – Meijer, H. A. J. 2020*: Radiocarbon Dating at Groningen: New and Updated Chemical Pretreatment Procedures. Radiocarbon 62, 1, 63–74. doi: 10.1017/RDC.2019.101.

*Deforce, K. – Bastiaens, J. – Crombé, P. 2014*: A reconstruction of middle Holocene alluvial hardwood forests (Lower Scheldt River, N-Belgium) and their exploitation during the Mesolithic-Neolithic transition period (Swifterbant Culture, c. 4500–4000 BC). Quaternaire 25, 1, 9–21.

*De Vries, H. – Barendsen, G. W. – Waterbolk, H. T. 1958*: Groningen radiocarbon dates II. Science 127, 3290, 129–137.

*Dohrn-Ihmig, M. 1971*: Untersuchungen an einem bandkeramischen Gräberfeld bei Niedermerz, Kr. Jülich. Germania 49, 175–9.

*Dohrn-Ihmig, M. 1983*: Das bandkeramische Gräberfeld von Aldenhoven-Niedermerz, Kreis Düren. In: G. Bauchhenß ed., Archäologie in den Rheinischen Lössbörden: Beiträge zur Siedlungsgeschichte im Rheinland, Köln: Rheinland-Verlag GmbH (Rheinische Ausgrabungen 24), 47–190.

*Dohrn-Ihmig, M. – Kuper, R. – Löhr, H. – Schröter, I. 1971*: Untersuchungen zur neolithischen Besiedlung der Aldenhoven Platte, Niedermerz 1. Bonner Jahrbuch 171, 633–60.

*Dreshaj, M. – Dee, M. – Brusgaard, N. – Raemaekers, D. – Peeters, H. 2023*: High-resolution Bayesian chronology of the earliest evidence of domesticated animals in the Dutch wetlands (Hardinxveld-Giessendam archaeological sites). PLOS ONE 18, 1, e0280619. doi: 10.1371/journal.pone.0280619.

*Dreshaj, M. – Dee, M. – Peeters, H. – Raemaekers, D. 2022*: Blind dates: Exploring uncertainty in the radiocarbon evidence on the emergence of animal husbandry in the Dutch wetlands. Journal of Archaeological Science: Reports 45, 103589. doi: 10.1016/j.jasrep.2022.103589.

*Dreshaj, M. – Raemaekers, D. – Dee, M. 2023*: Chronological modeling on a calibration plateau: Implications for the emergence of agriculture in the Dutch wetlands. Radiocarbon 65, 6, 1280–1298. doi: 10.1017/RDC.2023.126.

*Hedges, REM. – Housley, A. – Bronk Ramsey, C. – Van Klinken, G.* 1992: Radiocarbon dates from the Oxford AMS system: Archaeometry datelist 15. Archaeometry 34, 2, 337–57.

*Hedges, R. – Housley, R. – Bronk Ramsey, C. – Van Klinken, G. 1993*: Radiocarbon dates from the Oxford AMS system: Archaeometry datelist 17. Archaeometry 35, 2, 305–26.

*Heinen, M. 2010*: Niederkassel-Uckendorf: Eine bandkeramische Pioniersiedlung im Rheinland. In: D. Gronenborn & J. Petrasch eds., The Spread of the Neolithic to Central Europe: Interionational Symposium, Mainz 24 June-26 June 2005 (Part 2), Mainz: Verlag des Römisch-Germanischen Zentralmuseums, 517–34.

*Higham, T. F. G. – Bronk Ramsey, C. – Brock, F. – Baker, D. – Ditchfield, P. 2011*: Radiocarbon dates from the Oxford AMS System: Archaeometry datelist 34. Archaeometry 53, 5, 1067–1084. doi: 10.1111/j.1475-4754.2010.00574.x.

*Jadin, I. – Cahen, D. 2003*: Datations radiocarbones et Rubané: Pour un marriage de raison. In: I. Jadin ed., Trois petits tours et puis s'en vont: La fin de la présence danubienne en Moyenne Belgique, Liège: ERAUL (Études et Recherches Archéologiques de l 'Université de Liège 109)), 523–581.

*Knörzer, K.-H. 1973*: Pflanzliche Grossreste. In: J.-P. Farruggia, R. Kuper, J. Lüning, & P. Stehli eds., Der bandkeramische Siedlungsplatz Langweiler 2, Gemeinde Aldenhoven, Kreis Düren, Bonn: Rheinland-Verlag GmbH (Rheinische Ausgrabungen 13), 139–52.

*Knörzer, K.-H. 1988*: Untersuchungen der Früchte und Samen. In: U. Boelicke, D. Von Brandt, J. Lüning, P. Stehli, & A. Zimmerman eds., Der bandkeramische Siedlungsplatz Langweiler 8 Gemeinde Aldenhoven, Kreis Düren: Beiträge zuer neolithoschen besiedlung der aldenhover platte III 2, Köln: Rheinland-Verlag GmbH (Rheinische Ausgrabungen 28:2), 813–852.

*Lanting, J. N. – Van der Plicht, J. 2000*: De C14-chronologie van de Nederlandse pre- en protohistorie III: Neolithicum. Palaeohistoria 41/2, 1–110.

*Lodewijckx, M. 2009*: Frontier settlements of the LBK in central Belgium. In: D. Hofmann & P. Bickle eds., Creating communities: New advances in Central European Neolithic research, Oxford: Oxbow Books, 32–49.

*Louwe Kooijmans, L. P. 2001*: Synthese. In: L. P. Louwe Kooijmans ed., Hardinxveld-Giessendam-Polderweg: Een mesolithisch jachtkamp in het rivierengebied (5500-5000 v. Chr.), Amersfoort: Rijksdienst voor het Oudheidkundig Bodemonderzoek (Rapportage Archeologische Monumentenzorg 83), 441–70.

*Louwe Kooijmans, L. P. – Mol, J. 2001*: Stratigrafie, chronologie en fasering. In: L. P. Louwe Kooijmans ed., rcheologie in de Betuweroute: Hardinxveld-Giessendam De Bruin, Amersfoort: Rijksdienst voor Oudheidkundig Bodemonderzoek (Rapportage Archaeologische Monumentenzorg 88), 57–74.

*Menne, J. – Brunner, M. 2021*: Transition from Swifterbant to Funnelbeaker: A Bayesian Chronological Model. Open Archaeology 7, 1, 1235–1243. doi: 10.1515/opar-2020-0191.

*Meunier, K. 2013*: Chronologie de la céramique rubanée dans le Sud-Est du Bassin parisien. Bulletin de la Société préhistorique française 110, 3, 447–62.

*Modderman, P. 1970*: Linearbandkeramik aus Elsloo und Stein, Leiden: Leiden University (Analecta Praehistorica Leidensia 3).

*Peeters, H. 2007*: Hoge Vaart A27 in Context: Towards a Model of Mesolithic-Neolithic Land Use Dynamics as a Framework for Archaeological Heritage Management, PhD dissertation. Universiteit van Amsterdam.

*Porreij-Lyklema, A. – Van Wijk, I. M. 2012*: Sporen van de lineaire bandkeramische cultuur. In: I. M. Van Wijk, L. Meurkens, & A. Porreij-Lyklema eds., Opgraven langs de Rijksweg A2 te SteinHeidekampweg, Stein-Steinerbos en Geleen-Chemelot, Leiden: Archol (Archol rapport 150), 55–76.

*Quik, C. – Palstra, S. W. L. – van Beek, R. – van der Velde, Y. – Candel, J. H. J. – van der Linden, M. – Kubiak-Martens, L. – Swindles, G. T. – Makaske, B. – Wallinga, J. 2022*: Dating basal peat: The geochronology of peat initiation revisited. Quaternary Geochronology 72, 101278. doi: 10.1016/j.quageo.2022.101278.

*Raemaekers, D. C. M. – Aalders, Y. I. – Beckerman, S. M. – Brinkhuizen, D. C. – DeVriendt, I. – Huisman, H. – De Jong, M. – Molthof, H. M. – Prummel, W. – Niekus, M. J. L. Th. – Van der Wal, M. 2012*: The pre-Drouwen TRB settlement site Wetsingermaar, c. 3500 cal. BC (province Groningen, the Netherlands). Palaeohistoria 53/54, 1–24.

*Raemaekers. Daan C.M. 2015*: Rethinking Swifterbant S3 ceramic variability: Searching for the transition to the Funnel Beaker culture before 4000 calBC. In: J. Kabaciński, S. Hartz, D. C. M. Raemaekers, & T. Terberger eds., The Dąbki Site in Pomerania and the Neolithisation of the North European Lowlands, Rahden: Marie Leidorf GmbH (Archaeology and history of the Baltic 8), 321–34.

*Reimer, P. J. – Austin, W. E. N. – Bard, E. – Bayliss, A. – Blackwell, P. G. – Bronk Ramsey, C. – Butzin, M. – Cheng, H. – Edwards, R. L. – Friedrich, M. – Grootes, P. M. – Guilderson, T. P. – Hajdas, I. – Heaton, T. J. – Hogg, A. G. – Hughen, K. A. – Kromer, B. – Manning, S. W. – Muscheler, R. – Palmer, J. G. – Pearson, C. – van der Plicht, J. – Reimer, R. W. – Richards, D. A. – Scott, E. M. – Southon, J. R. – Turney, C. S. M. – Wacker, L. – Adolphi, F. – Büntgen, U. – Capano, M. – Fahrni, S. M. – Fogtmann-Schulz, A. – Friedrich, R. – Köhler, P. – Kudsk, S. – Miyake, F. – Olsen, J. – Reinig, F. – Sakamoto, M. – Sookdeo, A. – Talamo, S. 2020*: The IntCal20 northern hemisphere radiocarbon age calibration curve (0–55 cal kBP). Radiocarbon 62, 4, 725–757. doi: 10.1017/RDC.2020.41.

*Rose, H. A. – Meadows, J. – Henriksen, M. B. 2020*: Bayesian Modeling of Wood-Age Offsets in Cremated Bone. Radiocarbon 62, 2, 379–401. doi: 10.1017/RDC.2020.3.

*Salavert, A. – Zazzo, A. – Martin, L. – Antolín, F. – Gauthier, C. – Thil, F. – Tombret, O. – Bouby, L. – Manen, C. – Mineo, M. – Mueller-Bieniek, A. – Piqué, R. – Rottoli, M. – Rovira, N. – Toulemonde, F. – Vostrovská, I. 2020*: Direct dating reveals the early history of opium poppy in western Europe. Scientific Reports 10, 1, 20263. doi: 10.1038/s41598-020-76924-3.

*Scharl, S. – Gehlen, B. – Friedrich, R. – Knipper, C. – Meyer, C. – Suhrbier, S. 2022*: Die neolithischen Bestattungen von Müddersheim. Bonner Jahrbücher 222, 7–41.

*Schepers, M. – Woltinge, I. 2020*: Landscape development and stratigraphy. In: D. C. M. Raemaekers & J. P. De Roever eds., Swifterbant S4 (the Netherlands), Eelde: Barkhuis, 15–23. doi: 10.2307/j.ctv13nb6ns.4.

*Stapel, B. – Schneid, N. – Rosendahl, W. – Pollmann, H.-O. – Baales, M. 2012*: Neue datierte mesolithische Fundplätze und organische Artefakte aus Westfalen. Archäologie in Westfalen-Lippe 27–30.

*Stehli, P. 1973*: Keramik. In: J.-P. Farruggia, R. Kuper, J. Lüning, & P. Stehlie eds., Die bandkeramische Siedlungsplatz Langweiler 2, Gemeinde Aldenhoven, kreis Düren, Bonn: Rheinland-Verlag GmbH (Rheinische Ausgrabungen 13).

*Stehli, P. 1982*: Zur Methode der chronologische Gliederung des bandkeramischen Siedlungsplatzes Langweiler 8. In: J.Pavúk ed., Siedlungen der Kultur mit

Linearkeramik in Europa: Internationales Kolloquium, Nové Vozokany, 17.-20. Nov. 1981 (Nitra), Nitra, 271–7.

*Stehli, P. 1989*: Zur relativen und absoluten Chronologie der Bandkeramik in Mitteleuropa. In: J. Rulf ed., Bylany Seminar 1987: Collected papers, Praha: Archaeological institute of the Czechoslovak academy of sciences, 69–78.

*Teetaert, D. 2020*: Routes of Technology: Pottery Production and Mobility during the Mesolithic-Neolithic Transition in the Scheldt River Valley, PhD dissertation. Universiteit Gent.

*Teetaert, D. – Boudin, M. – Goemaere, E. – Crombé, P. 2020*: Reliability of AMS 14C dates of moss temper preserved in Neolithic pottery from the Scheldt river valley (Belgium). Radiocarbon 62, 6, 1667–1678. doi: 10.1017/RDC.2019.148.

*Van der Velde, P. 2008*: On chronology: pot sherds, house ghosts, and carbonized seeds. In: P. Van der Velde ed., Excavations at Geleen-Janskamperveld 1990/1991, Leiden: Leiden University (Analecta Praehistorica Leidensia 39), 205–22.

*Van Strydonck, M. – Crombé, P. 2005*: Features: radiocarbon dating. In: P. Crombé ed., The Last Hunter-Gatherer-Fishermen in Sandy Flanders (NW Belgium). The Verrebroek and Doel Excavation Projects. Volume 1: Palaeo-environment, Chronology and Features, Ghent: Academia Press, 180–212.

*Van Wijk, I. M. 2022*: The pottery of the burial ground of Elsloo. In: I. M. Van Wijk & L. W. S. W. Amkreutz eds., Elsloo-Koolweg Revisited: Science-based perspectives on the burials and grave goods of the Linear Bandkeramik burial ground of Elsloo-Koolweg, Amersfoort: Cultural Heritage Agency of the Netherlands (Nederlandse Archeologische Rapporten 76), 99–114.

*Van Wijk, I. 2016*: The Linear Bankeramik Settlement. In: I. Van Wijk ed., Settlement dynamics on the Cannerberg: Archaeological research of the Bandkeramik and Iron Age settlements, Leiden: Archol (Archol Report 300), 91–140.

*Vogel, J. – Waterbolk, H. 1963*: Groningen radiocarbon dates IV. Radiocarbon 5, 163–202.

*Von Brandt, D. 1988*: Häuser. In: U. Boelicke, D. Von Brandt, J. Lüning, P. Stehli, & A. Zimmerman eds., Der bandkeramische Siedlungsplatz Langweiler 8, Gemeinde Aldenhoven, Kreis Düren, Bonn: Rheinland-Verlag GmbH (Rheinische Ausgrabungen 28/1), 36–289.

*Waterbolk, H. T. 1959*: Die bandkeramische Siedlung van Geleen. Palaeohistoria VI–VII, 9–161.