Constructing chronologies with ChronoModel
Practical Part

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First modelling with ChronoModel (Part I)

Creating a simple model

Including measurements using the icons

Understanding the marginal posterior densities and the summary statistics

The example of Lezoux

Medieval kiln of the potter's workshop in Lezoux (Auvergne, France)[1]

Aim : Dating the last firing of the kiln

[1] Menessier-Jouannet *et al.* 1995

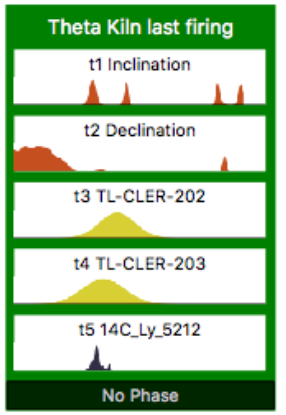
Lezoux - Modelling

- **Prior information** about the date of the last firing (θ) : any date between 0 and 2 000

  $>$ Prior distribution, $\theta \sim U_{[0,2000]}$

- **Material found** :
  - baked clays dated by
    AM $>$ *Estimation of the last time the temperature exceeded a critical point*
    TL $>$ *Estimation of the last firing*
  - bones
    14C $>$ *Estimation of the death of the animal*

$=>$ **Assumption of contemporaneity** (Event model)

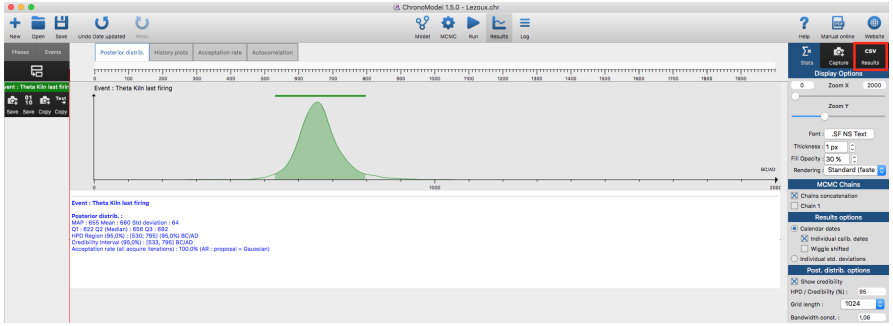


Lezoux - data

Exercice : build your first project using the following information

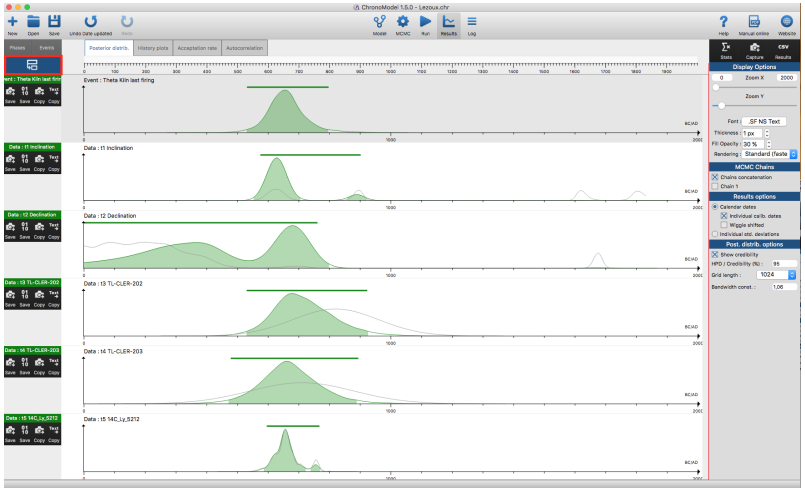
- **Create a new project**
- **Define the study period** : 0 to 2 000
- **Create a new event** corresponding to the date of the last firing
- **Include measurements**
  T1 : (AM) Inclination : I = 69.2, alpha = 1.2
  T2 : (AM) Declination : I = 69.2, alpha = 1.2, D= -2.8
  T3 : (TL) age 1170 +/- 140 years - Reference year : 1990
  T4 : (TL) age 1280 +/- 170 years - Reference year : 1990
  T5 : (14C) age 1370 +/- 50 BP

Marginal posterior density of the Event and summary statistics

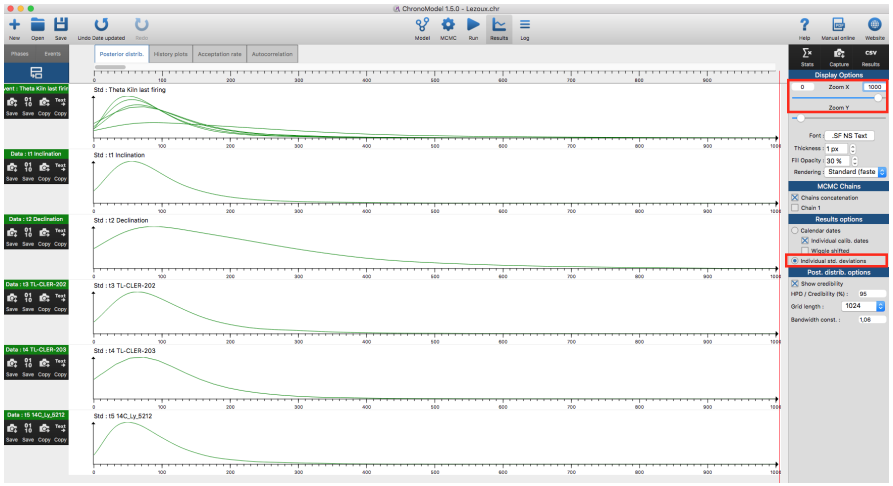


The segment above the curve represents the smallest credible interval.
The HPD region is presented by the colored area under the curve.

Marginal posterior densities of the Event and the dates



Marginal posterior densities of the individual standard deviations σ_i



First modelling with ChronoModel (Part II)

Creating a CSV file containing the measurements

Importing a CSV file into ChronoModel

Dragging several lines into an event

Lezoux - data

Exercice : build your own CSV file containing the following dates

See the User's manual pages 27 to 30 for the details

- **T1** : (AM) Inclination : I = 69.2, alpha = 1.2
- **T2** : (AM) Declination : I = 69.2, alpha = 1.2, D= 2.8
- **T3** : (TL) age 1170 +/- 140 years - Reference year : 1990
- **T4** : (TL) age 1280 +/- 170 years - Reference year : 1990
- **T5** : (14C) age 1370 +/- 50 BP

CSV file - Archaeomagnetism dates

Archeomagnetism measurements:

Cell 1 : AM, the type of measurement

Cell 2 : Name, the name of the dated sample

Cell 3 : Type, "inclination", "declination" or "intensity"

Cell 4 : Inclination value

Cell 5 : Declination value

Cell 6 : Intensity value

Cell 7 : Error (sd) or alpha 95, the degree of alpha 95 associated with the inclination / declination value or the standard error associated with the intensity value

Cell 8 : Reference curve, the name of the file containing the reference curve associated with the measurement

The content of any following cells will be ignored (so these can be used for comments).

See Figure 3.18 for an example.

	A	B	C	D	E	F	G	H
1	AM	My AM date 1	inclination	25	0	0	1	gal2002sph2014_i.ref
2	AM	My AM date 2	declination	25	60	0	1	gal2002sph2014_d.ref
3	AM	My AM date 3	intensity	0	0	56	1	gwh2013uni_f.ref
4								

CSV file - Thermoluminescence dates

Thermoluminescence measurements:

Cell 1 : TL/OSL, the type of measurement

Cell 2 : Name, the name of the dated sample

Cell 3 : Age, the value of the measurement

Cell 4 : Error (sd), the standard error of the measurement

Cell 5 : Reference year, the year of the dating of the sample

The content of any following cells will be ignored (so these can be used for comments).

See Figure 3.16 for an example.

	A	B	C	D	E	F
1	TL/OSL	My TL/OSL date 1	520	30	2010	
2	TL/OSL	My TL/OSL date 2	1250	30	2010	
3						

Figure 3.16 – Example of a CSV file containing TL/OSL datings

CSV file - Radiocarbon dates

Radiocarbon measurements:

Cell 1 : 14C, the type of measurement

Cell 2 : Name, the name of the dated sample

Cell 3 : Age, the value of the measurement

Cell 4 : Error (sd), the standard error of the measurement

Cell 5 : Reference curve, the name of the file containing the reference curve associated with the measurement

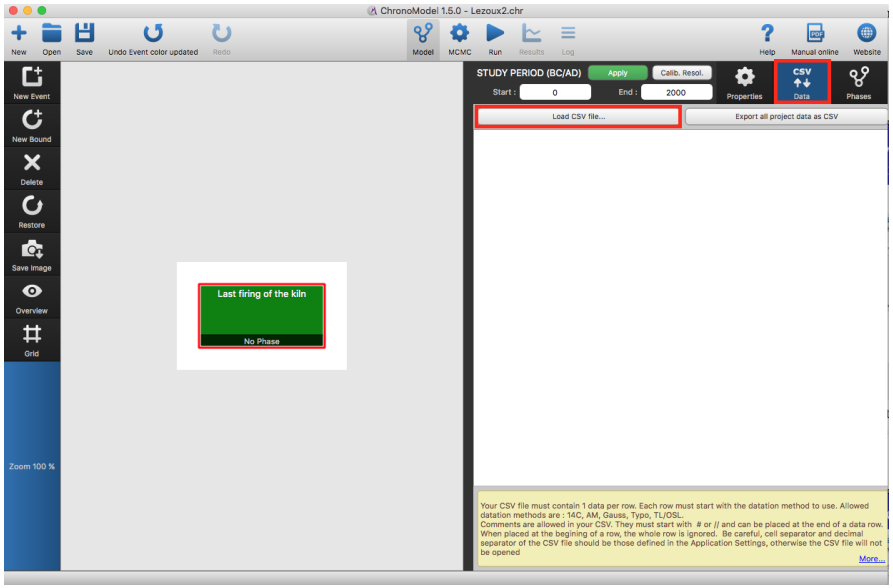
Cell 6 : Reservoir effect, the value of the reservoir effect if any

Cell 7 : Error of the reservoir effect, the value of the error associated, if any

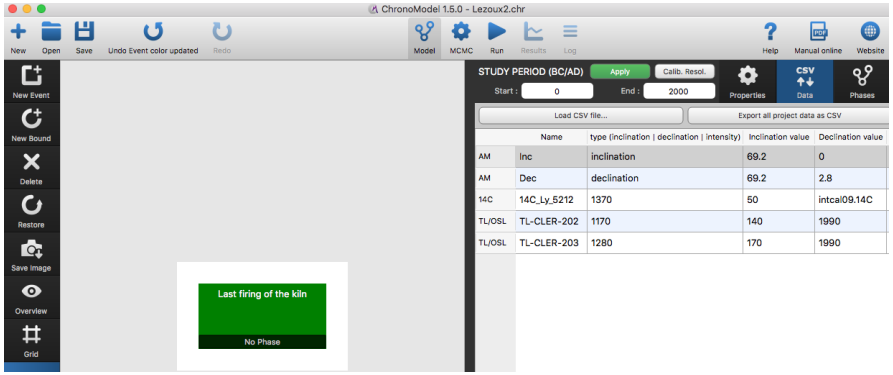
	A	B	C	D	E	F	G	H	I	J
1	14C	My radiocarbon date 1	3432.37	13.3934	intcal09.14c	0	0			
2	14C	My radiocarbon date 2	3452	50	intcal04.14c	0	0	gaussian	12	2
3	14C	My radiocarbon date 3	3432.37	13.3934	intcal09.14c	0	0	fixed	15	
4	14C	My radiocarbon date 4	3452	50	intcal04.14c	0	0	range	0	200
5										

Figure 3.17 – Example of a CSV file containing radiocarbon datings

Loading a CSV file



Import successful or not ?

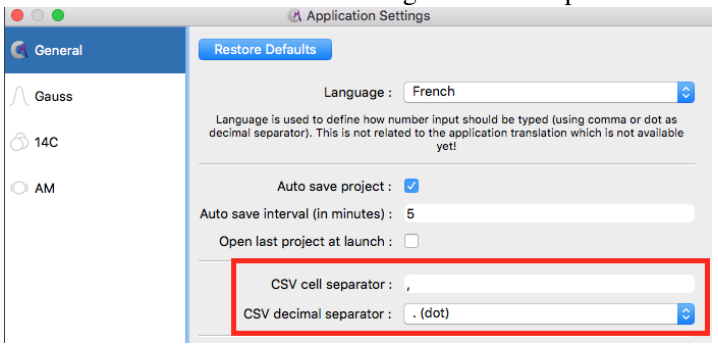


If data does not appear, check whether ChronoModel is set to read a CSV file that have the same separators as those of your CSV file.
To check that, go to the Prefences Settings of ChronoModel

Prefences Settings

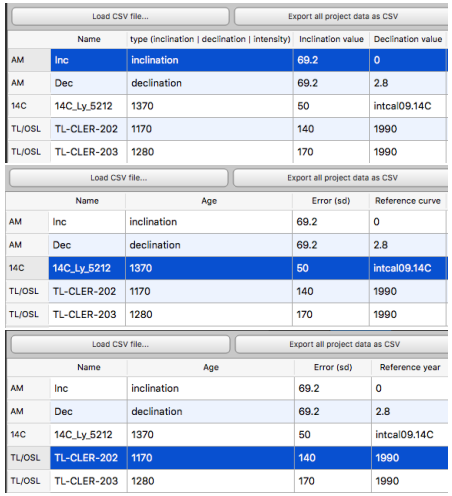
```
//,ident,mesure,err,Lezoux,,,
AM,Inc,inclination,69.2,0,0,1.2,GAL2002sph2014_I.ref
AM,Dec,declination,69.2,2.8,0,1.2,GAL2002sph2014_D.ref
14C,14C_Ly_5212,1370,50,intcal09.14C,,,
TL/OSL,TL-CLER-202,1170,140,1990,,,
TL/OSL,TL-CLER-203,1280,170,1990,,,
```

Here, the CSV file uses "," as cell separator and "." as decimal separator. Make sure that in the ChronoModel settings the same separators are selected.



Reading data loaded

Click on the type of measurement on the left (AM, 14C, TL/OSL), the label of the columns will change according to the type

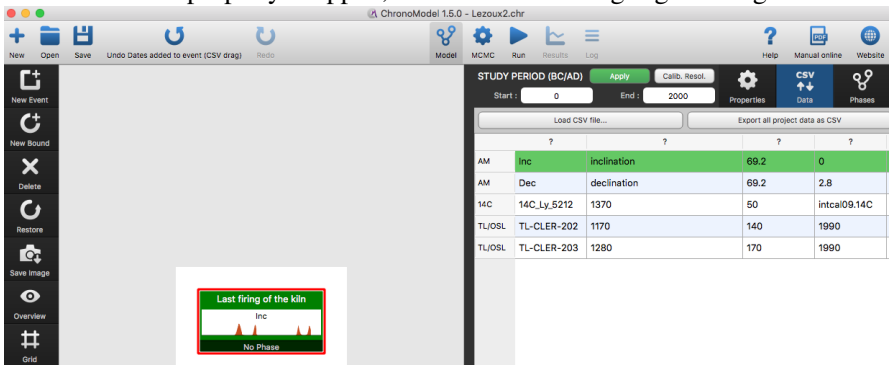


Dragging one line

In order to associate a measurement to an event,

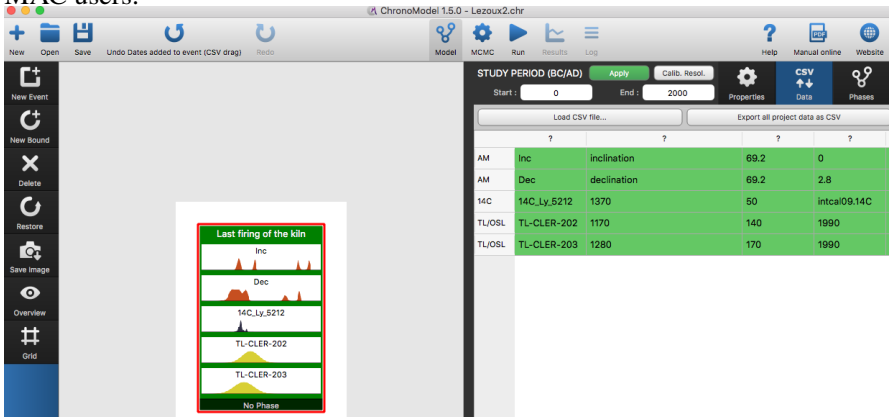
- select the line by clicking on its type (AM, 14C, ...), now the line should be highlighted in blue
- select it anywhere highlighted in blue
- then drag the line and drop it in an event

Once the line is properly dropped, then it should be highlighted in green.



Dragging several lines

Select the lines using the keyboard "Ctrl" for Windows users or command ⌘ for MAC users.



Second modelling with ChronoModel

Importing a CSV file

Adding bounds and temporal order constraints

Defining a group of events / a phase

Understanding the marginal posterior densities of such a phase

The example of Sennefer's burial

Sennefer was tomb the "Mayor of the city" (Thebes) during the 18ième dynasty
(Der el Medina, Egypt)[2]

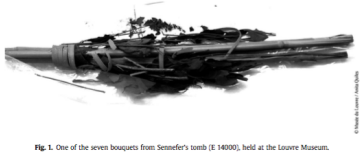


Fig. 1. One of the seven bouquets from Sennefer's tomb (E 14000), held at the Louvre Museum.

Aim : Dating Sennefer's burial using the bouquets of flowers found at the entrance of the tomb

[2] Quiles *et al.* 2013

Sennefer's burial - A modelling

- **Prior information** about Sennefer's death (or the death of the flowers constituting the bouquets) :

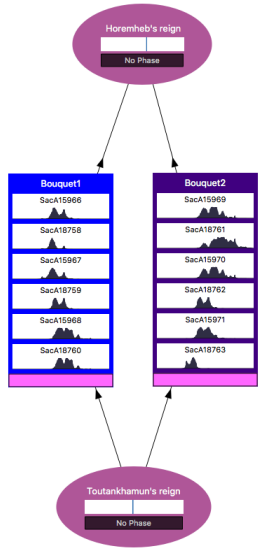
> 18th Egyptian dynasty

- **Prior information about the historical context** :

"[...] occurred between the beginning of the reign of Tutankhamun and the beginning of the reign of Horemheb [...] "

- **Material found** :
Several samples per bouquet dated by **14C**

- **Group of events** :
To date the burial of Sennefer, let's gather both events into a phase



Sennefer's burial - Data

Exercice : build a new project in order to date the burial of Sennefer

- **Create a new project**
- **Define the study period** : Let's take -1700 à -1000
- **Create a new event** corresponding to the cut of the flowers of Bouquet 1
- **Create a new event** corresponding to the cut of the flowers of Bouquet 2
- **Create two bounds** corresponding to the beginning of the reign of Tutankhamun (-1356) and the beginning of the reign of Horemheb (-1312)
- **Include measurements**
import the CSV file that contains the radiocarbon dates
- **Create a phase** including both events

Adding a temporal order constraint

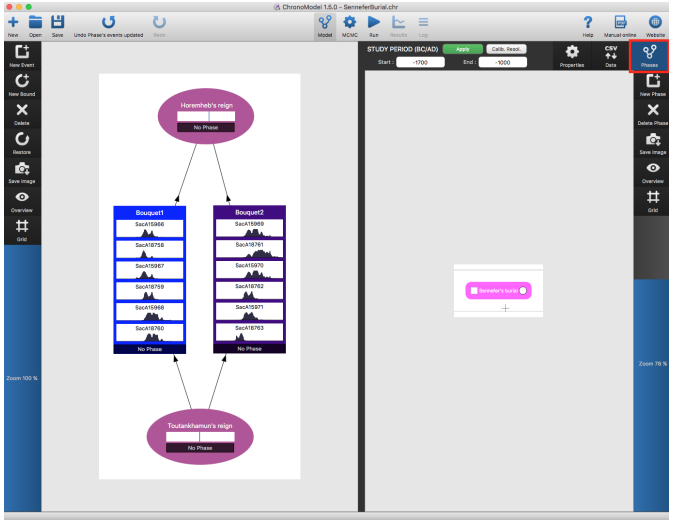
In order to add a temporal order constraint between two events/bounds, follow the steps

- Both events/bounds should already be created
- Start by clicking on the oldest event/bound
- Then press the "Alt" key and move the mouse toward the youngest event/bound
- Keep pressing the "Alt" key and now click on the youngest event/bound

Once done, an arrow should link both events/bounds heading from the oldest event/bound to the youngest one.

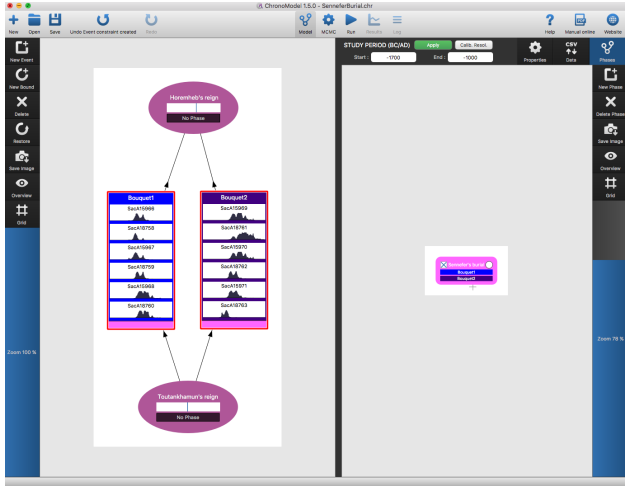
Creating a phase

Select the "Phases" tab as done below and create a new phase

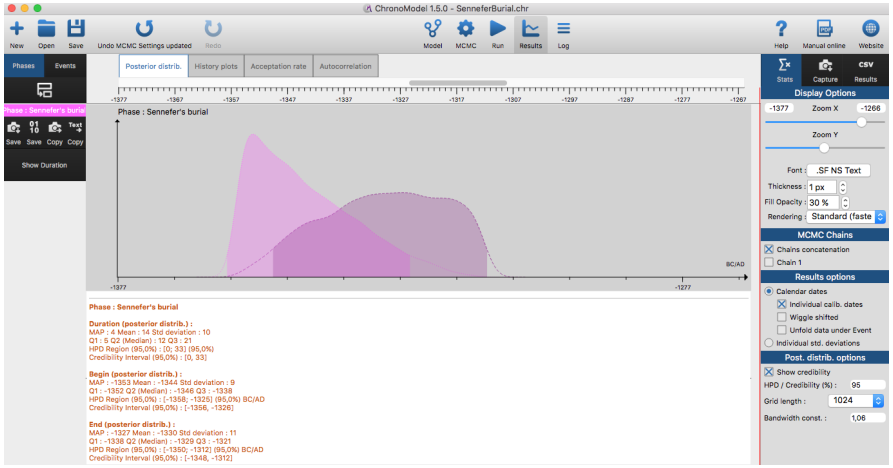


Including events/bounds in a phase

Select all events/bounds using the "Ctrl" key and then click in the square box of the phase as done below

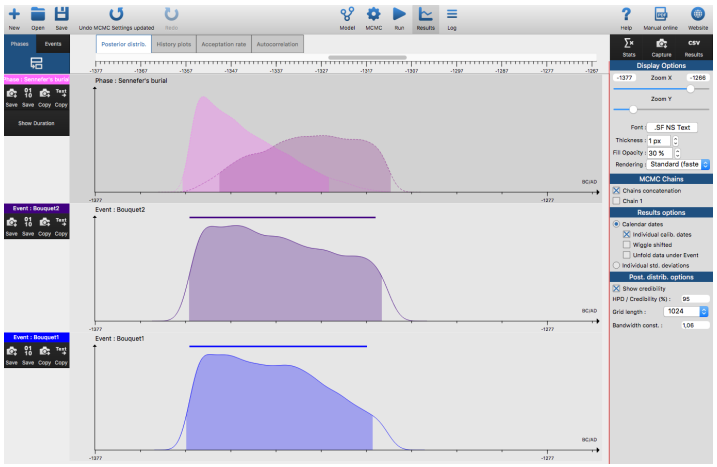


Marginal posterior densities of a phase



On the first graph, the beginning of the phase is drawn in pink, the end of the phase is drawn in light purple.

Marginal posterior densities



Post-treatment of the simulated Markov Chains

Extracting data from ChronoModel

Using the ArchaeoPhases application

Drawing a Tempo plot

Drawing Time range intervals, Transition ranges

Testing the existence of a hiatus between successives phases

The example of Ksâr 'Akil

A key Paleolithic site with a deep stratigraphic sequence (Ksâr 'Akil, Lebanon)[3]

Aim : Dating the chronology of the Paleolithic phases using the stratigraphic relationships and the measurements made on the shells found in the sequence

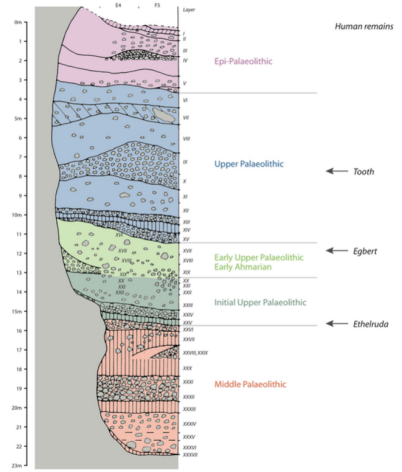


Figure S1.2. Ksâr 'Akil stratigraphic sequence (redrawn after (6) with reference to the major archeological divisions and human remains).

[3] Bosch *et al.* 2015

Ksâr 'Akil - A modelling

- **Modelling choices**

> an event : the death of a shell

> a layer : group of events

> Paleolithic phase : group of successive layers

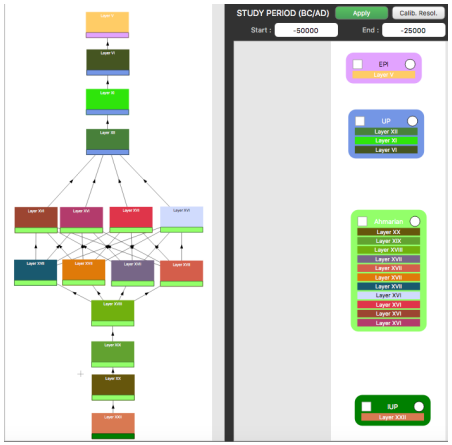
- **Prior information**

> study period = -50 000 to -25 000

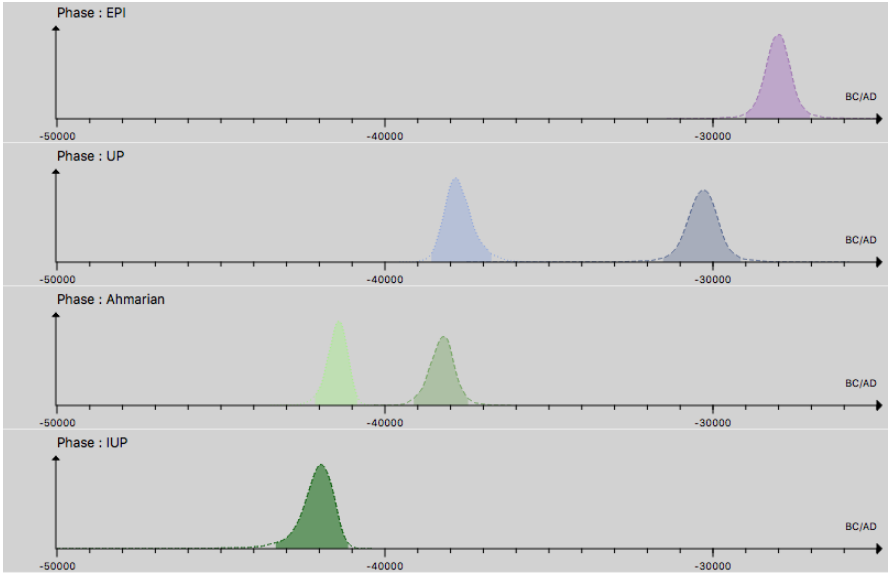
> stratigraphic relationships between the successive layers

- **Material found**

16 shells dated by **14C**



Ksâr 'Akil - Marginal posterior densities



Ksâr ’Akil - More information

- **Phase time range**

The shortest interval that covers the beginning and the end of the phase at 95%

- **Transition between two successive phases**

The shortest interval that covers the end of a phase and the beginning of a successive phase

- **Test for existence of a Gap between successive two phases** :

If it exists, the longest interval between the end of a phase and the beginning of a successive phase.

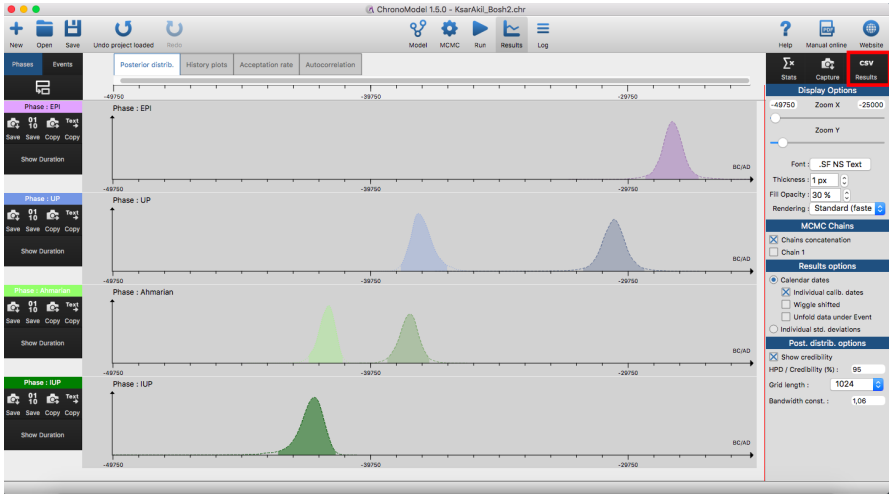
> Let’s extract the Markov chains from ChronoModel and use the R package RChronoModel or the web application ArchaeoPhases

Ksâr ’Akil - Exercice

Exercice :

- Open the project KsarAkil.chr and run the MCMC
- Extract the resulted Markov chains using "CSV results"
- Define all the files saved in the new directory
- Open the application called ArchaeoPhases
  Click here to load the ArchaeoPhases app
- Load "events.csv" and use the tab called "Dates" to draw a tempo plot
- Load "phases.csv" and use the tab called "Phases" to look at the plot of several phases
- Use the tab called "Succession of phases" to look at the plot of the succession

Ksâr ’Akil - Extracting CSV files

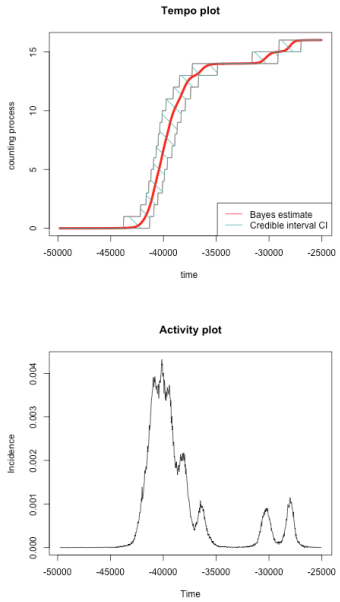


Ksâr ’Akil - Files extracted

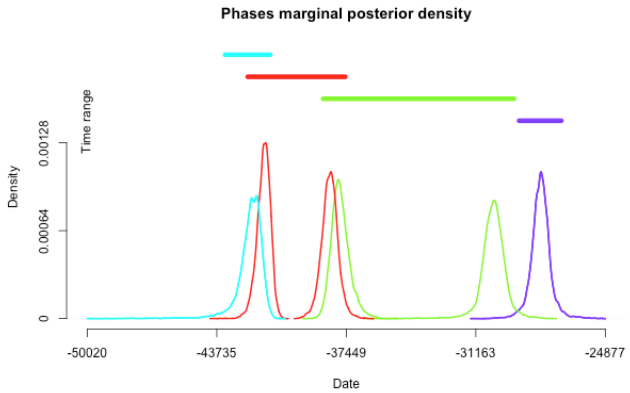
events.csv
MCMC_Initialization.html
Model_description.html
phase_ahmarian.csv
phase_epi.csv
phase_iup.csv
phase_up.csv
phases.csv
Posterior_dis..._results.html
Stats_table.csv

events : Markov chains of all events
phases : Markov chains of all phases (beginning and end)
Stats table : Summary statistics of all dates and phases (beginning and end)

Tempo plot : Rhythm of the occurrence of events

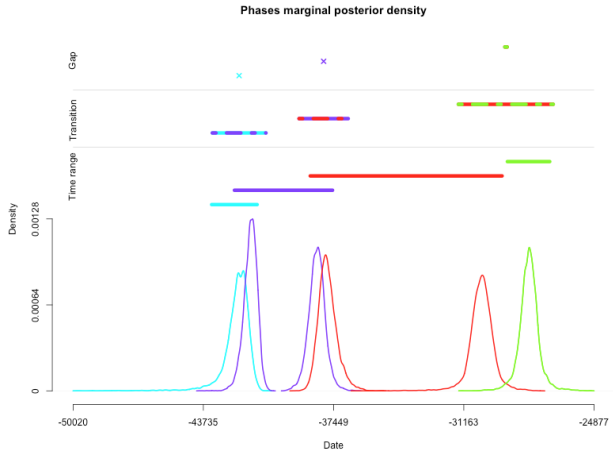


Plot of the Paleolithic phases



Marginal posterior densities of the beginning and the end of the following phases : IUP (in blue), Ahmarian (in red), UP (in green), and EPI (in purple) with their time range interval (segment above the curves) at 95%.

Plot of the succession of the Paleolithic phases



Two-coloured segments correspond to transition interval or to the gap range. There is no gap interval at 95% between IUP and Ahmarian, and Ahmarian and UP, but one exists between UP and EPI.

Summary - Modelling steps

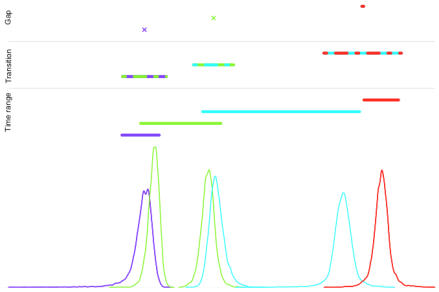
1. What is your **problematic** ? Which **target events** do you want to date ?
2. Do you have **measurements** associated with those events ? Otherwise, you won't be able to estimate their date.
3. Are there any **temporal relationship** between those target events ?
4. Are there any ***Terminus post quem* / *Terminus ante quem*** ?
   If so include bounds and arrows between bounds and events
5. Are you interested in **groups of events** / environmental or geographical phases / periods ?
   If so include phases
6. Are there any **temporal relationships between these phases** ?
   If so include arrows between successive phases
7. Do you have any **prior information about those groups of events** ? A maximum duration or the existence of a hiatus ?

Summary - Modelling steps

- Do your modelling with either ChronoModel or Oxcal
- Extract the MCMC samples
- Use the ArchaeoPhases app to get post-treatment informations

www.chronomodel.fr

RChronoModel



ArchaeoPhases (click here)