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Exploration of analytical and experimental study of the Neolithic heatedstones fire structures of the Louviers Site "ZAC Côte de la Justice" in Eure France

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David Aoustin, Quentin Borderie

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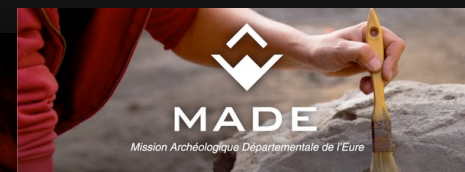


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EXPLORATION OF ANALYTICAL AND EXPERIMENTAL STUDY OF THE NEOLITHIC HEATED STONES FIRE STRUCTURES OF THE LOUVIERS SITE "ZAC CÔTE DE LA JUSTICE" IN EURE FRANCE

R. J. March¹, C. Rodriguez Loredo¹, V. Dartois², L. Gaudin¹, Q. Borderie², D. Aoustin¹

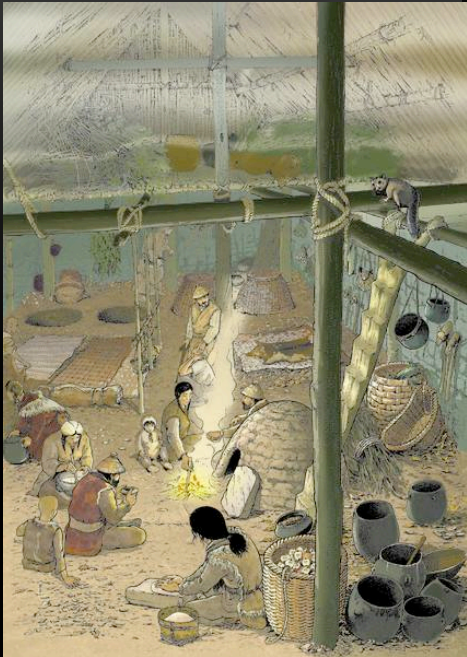
UMR 6566 CReAAH¹ MADE²



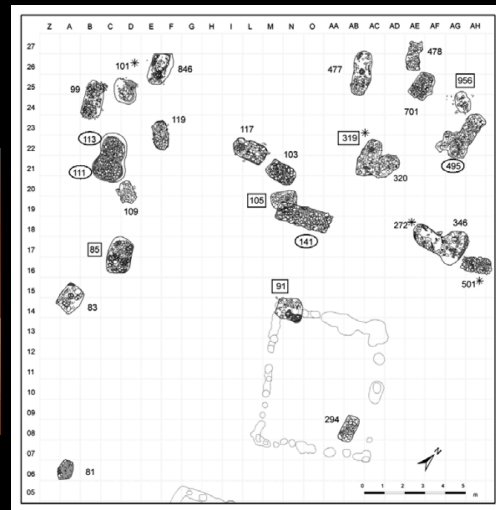
Session 39 Hearths, ovens and cooking spaces in the Mediterranean from the Late Prehistory to the Middle Ages. September 4, 2025



"Domestic" fires in agro-pastoral societies



Les Sablins Piningre 1991



Carnac Thoron 2017

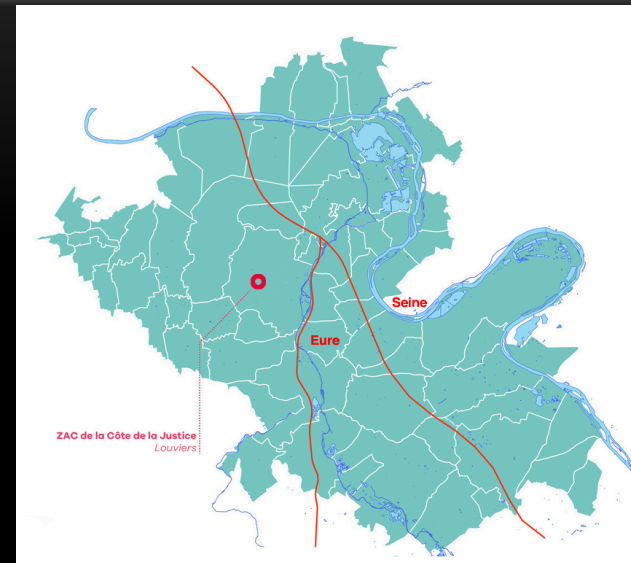
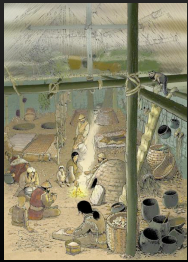
S. Andrea Travo 2016

Melanesian ovens
in late European
prehistory, of the
north west of
France
Functions?
Domestic,
artisanal or
symbolic
answers?



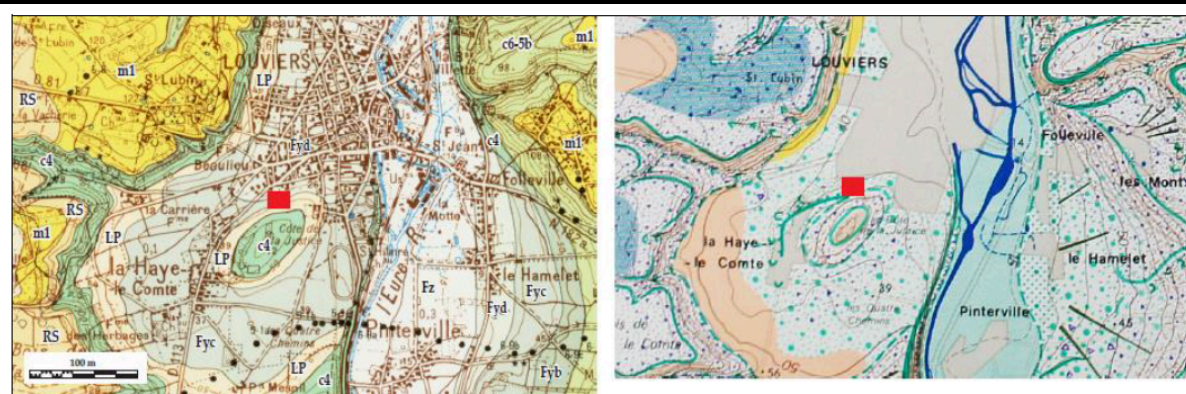
Towards a history of fire: searching to interpret and build

Analytical and experimental study of the Neolithic heated stones fire structures of the Louviers site "Zac Côte de la Justice" in Eure France



The site is situated in the Eure region at the north-west region of France. The occupation of the site extends from the ancient Neolithic to the Bronze Age. We were able to study two structures with heating stones belonging to the Middle and Ancient Neolithic.

- Study of heating stone combustion structures
- Structures using heated silex
- Analysis of the mode of use and function of these structures
- By experimental and analytical means
- Thermal transformations of soils and rocks
- Lipid analysis by
 - GC-C, GC-MS &
 - CG-C-IRMS

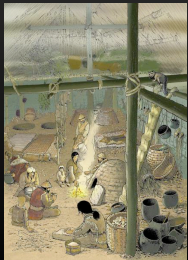


Geographic Louviers Localisation and in geologic and geomorphologic maps from (Bassompierre and de Maurtort 1967 and Dewolf 1975)



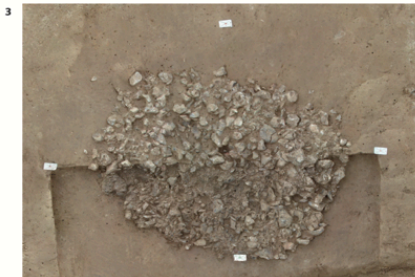
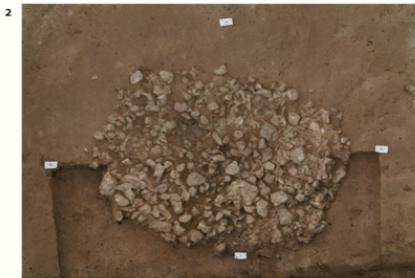
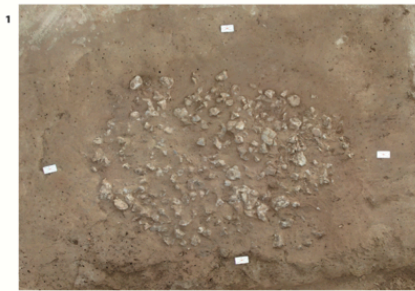
Towards a history of fire: research to analyze, interpret and build

• Structure 221, 4457 & 4352 (95,4%) BC, Middle Neolithic

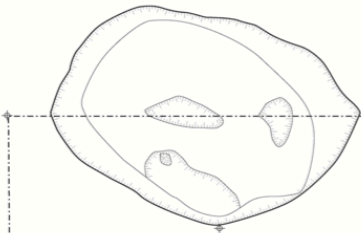
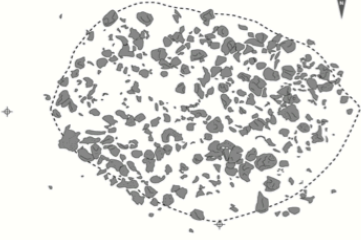


Heating stone combustion structures

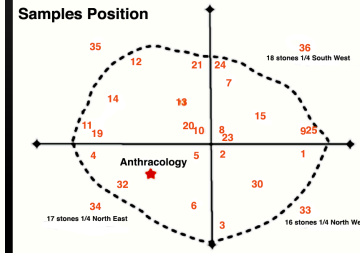
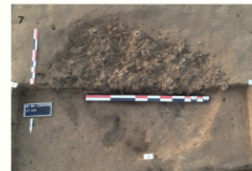
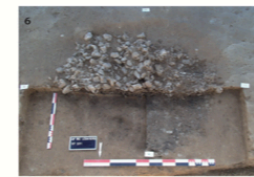
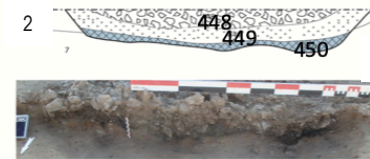
- Heating stone combustion structures
- High consumption of animal fats
- Presence of vegetal lipids
- Indirect cooking of meat on rocks
- Presence of deer and hunting and domestic animals



V. Dartois MADE with modifications



• Fire structure 221



⊗ Charcoaled sediment	■ Charcoal
■ Ashes sediment	■ Heated
⊙ Flint high fractured	★ Samples

SU 448: Flint blocks and pebbles more or less burnt and fractured in a brown - grey clayey lime matrix Homogeneous and compact

SU 449: flakes of burnt flint in a brown - grey silty matrix

SU 450: Grey to ashy black loam and charcoal with the presence of some burnt flint flakes

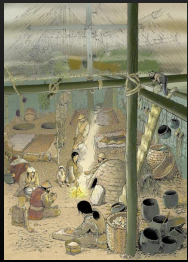
SU 2 Horizon BT degraded brown clay limestone, prismatic with dark aggregates, ferro-manganese stains in the upper layer, little bioturbated, rootlets, some small flint grains

Su 7: Paleosol archaeological layer, grey yellow to orange silty, has lighter beaches, massive with many vesicles, little bioturbated, some iron-manganese nodules (1-2 mm) a few charcoals (3mm)

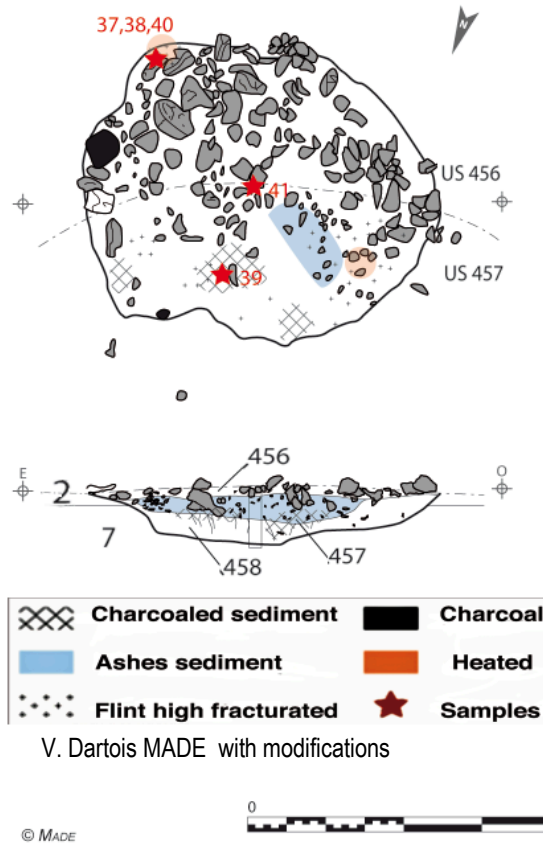
Varying cooking modes in combustion structures, Grilled, Roasted - on hot stones Grill,



• Structure 236 Ancient Neolithic, 4911 et 4722 BC (93,4%)



Fire structure 236



SU 456: Flint blocks and pebbles more or less burnt and fractured in a brown - grey clayey lime matrix Homogeneous and compact with some fragments of charcoals
 Note: presence of more voluminous blocks in the couronne of South part

SU 457: Grey to ashy black loam and charcoal with the presence of some burnt flint flakes and important quantity of flakes , more rubified zones was observed at South-East and South West parts that have a more important concentration of flint burnt flakes

SU 458: Heterogeneous orange clayey loam marked by percolation marks with layer 457, presence of tongues from cinder to carbonaceous and puncture and small flint pebbles

SU 2 : Horizon BT degraded orange-brown clay limestone, prismatic with dark aggregates, ferro-manganese stains in the upper layer, little bioturbated, rootlets, some small flint grains

SU 7: Paleosol archaeological layer, grey yellow to orange silty, has lighter beaches, massive with many vesicles, little bioturbated, some iron-manganese nodules (1-2 mm) a few charcoals (3mm).

•Heating stone combustion structures

•Chemical molecular analysis

•Presence of lipids hydrocarbons fats grasses and residues related to the fuels used

•Presence of animal fats

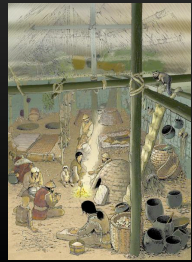
•Use of rocks for indirect cooking of food

The dates of both structures seem to confirm the assignation of these structures to the Chambon culture but also show an more important period of occupation of the site and even the possibility of their reutilisation.



Heating stone combustion structures

Analyses of heated flints a contribution to the study of human behaviour in relation



- [Louviers site](#)
- [Structure 221](#)
- [4457 et 4352 \(95.4%\) BC](#)
- [Middle Neolithic](#)

Heated stones fires structures

- Study of heating flint stone combustion structures
- Analysis of their mode of functioning by an experimental approach
- Analysis of their thermal behavior and thermal alteration of rocks and sediments

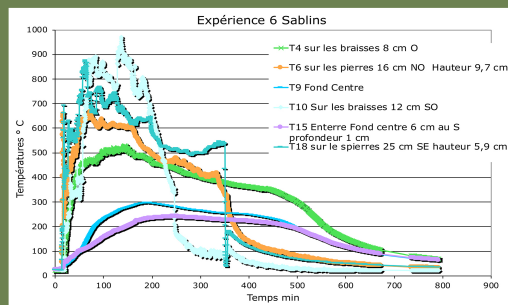


Towards a history of fire: Rebuild to understand

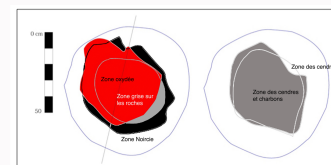
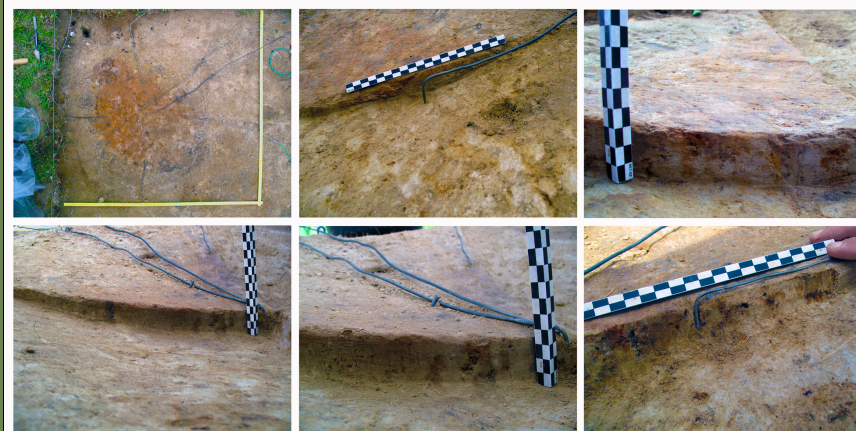
The site of Louviers «Zac Cote de la Justice» the heated flint structures. Their mode of functioning

Heated stones fires structures

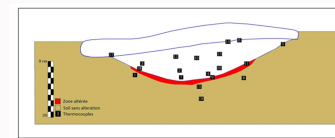
- Study of heating flint stone combustion structures
- Analysis of their mode of functioning by an experimental approach
- Analysis of their thermal behavior and thermal alteration of rocks and sediments



Experiment 6 Sablins : flints were heated over and rise temperatures between 526° C et 870° C . The bottom of the bowl reached 300° C over such a short period of time in the center of the structure below the flint, but it reached higher temperatures between 380° C and 400° C at 20 cm around the bottom center of the structure where temperatures were lower.



Zones altérées expérience n°6



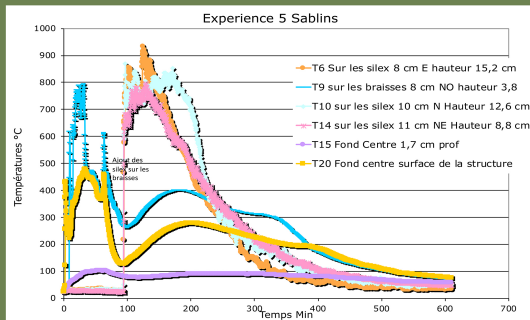
Zones altérées expérience n°6 et position des thermocouples

Study from experimental data on the distribution of traces of thermal alterations on rocks and soils

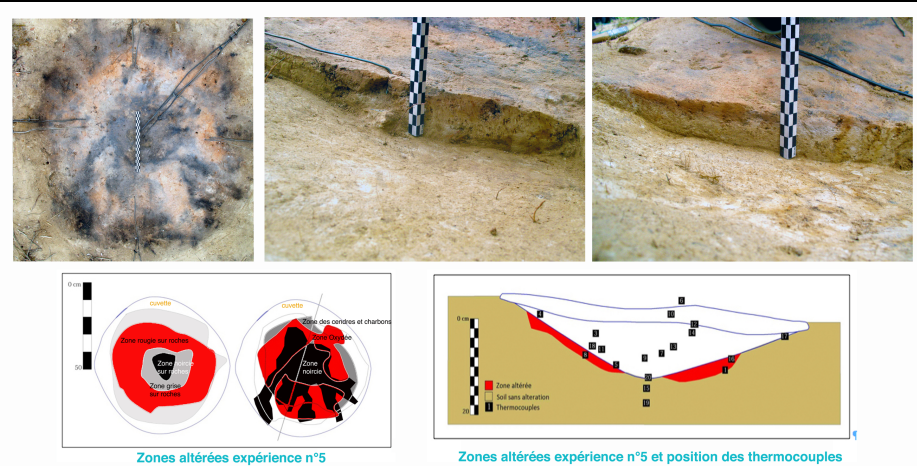


The site of Louviers «Zac Cote de la Justice» the heated flint structures. Their mode of functioning

REBUILD TO UNDERSTAND



Experiment 5 Sablins : Flint temperatures between 400°C & 932 °C
The bottom of the bowl below the embers for experiment 5 reached temperatures between 300°C and 476°C (Fig.n°52), for a short period of only 40 minutes after ignition and before the deposit of flints on the embers that smothered the fire in the structure, to after remain below 300°C and even after the fire was rekindled from below the flints



Structure 236 Louviers



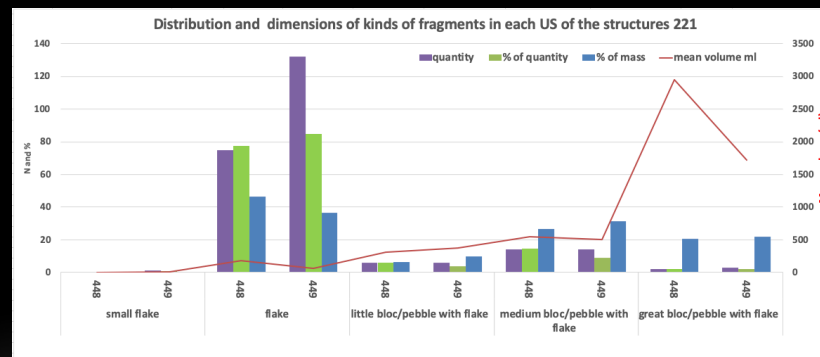
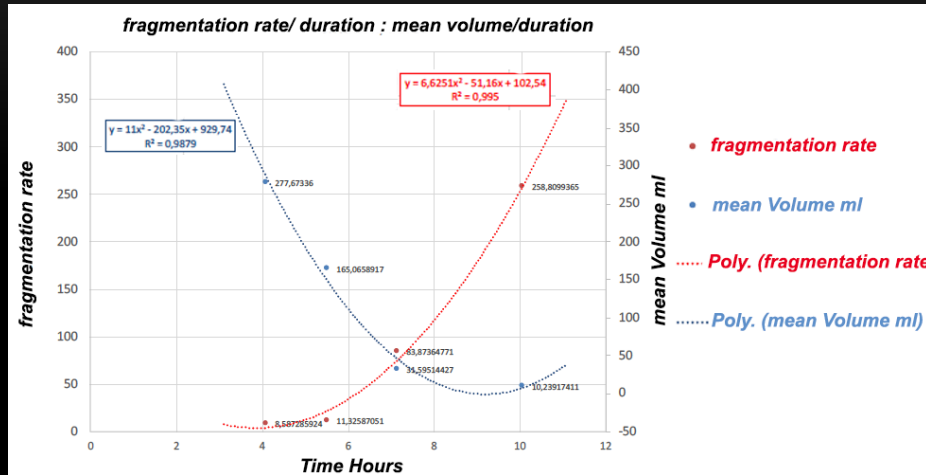
Study from experimental data on the distribution of traces of thermal alterations on rocks and soils



Towards a history of fire: Rebuild to understand

The site of Louviers «Zac Cote de la Justice» the heated flint structures. Their mode of functioning

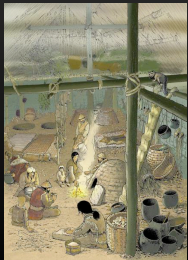
REBUILD TO UNDERSTAND



Study from experimental data on the distribution of traces of thermal alterations on rocks and soils

Towards a history of fire: Rebuild to understand

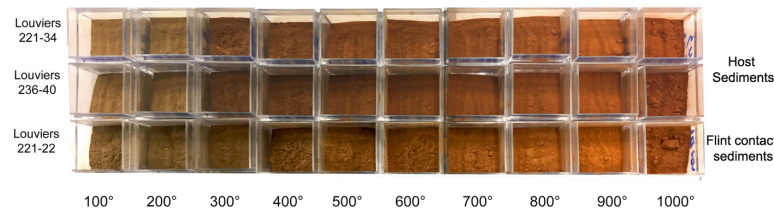
Louviers Site «Zac Cote de la Justice » the mode of functioning of the Heated stones fires structures



Munsell Colors of thermalaltered sediments

	Louviers 221-34	Louviers 221-22	Louviers 236-40
20°C	6/4 light yellowish brown 10 YR	6/4 light yellowish brown 10 YR	6/3 pale brown 10 YR
100°C	6/4 light yellowish 10 YR	6/4 light yellowish 10 YR	6/3 pale brown 10 YR
200°C	6/4 light yellowish 10 YR	6/4 light yellowish 10 YR	6/3 pale brown 10 YR
300°C	5/4 brown 7.5 YR	5/4 brown 7.5 YR	5/4 yellowish brown 10 YR
400°C	6/6 reddish yellow 7.5 YR	6/4 light brown 7.5 YR	6/4 light brown 7.5 YR
500°C	5/6 strong brown 7.5 YR	5/6 strong brown 7.5 YR	6/6 reddish yellow 7.5 YR
600°C	5/6 strong brown 7.5 YR	5/6 strong brown 7.5 YR	6/6 reddish yellow 7.5 YR
700°C	5/8 strong brown 7.5 YR	5/8 strong brown 7.5 YR	6/6 reddish yellow 5 YR
800°C	6/8 reddish yellow 5 YR	6/8 reddish yellow 5 YR	6/6 reddish yellow 5 YR
900°C	5/8 reddish yellow 5 YR	5/8 reddish yellow 5 YR	6/8 reddish yellow 5 YR
1000°C	5/8 reddish yellow 5 YR	5/8 reddish yellow 5 YR	5/6 yellowish red 5 YR

Sediments transformation under heat effect



•Study of heating stone combustion structures

•Analysis of thermal alteration of rocks And sediments

Mode of heat exposure from the top of flints.

This heating modality observed experimentally, causes a slight insulation of the floors and walls of the bowl that prevent a significant oxidation of the substrates as was observed during our experiments where the oxidation although present has reached a very slight thickness.

Reused structures

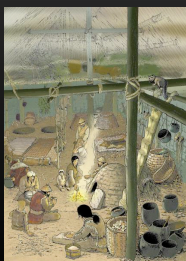
The duration of heated is short and repeated we could consider a recurrent and domestic use for these structures.

Heated stones fires structures



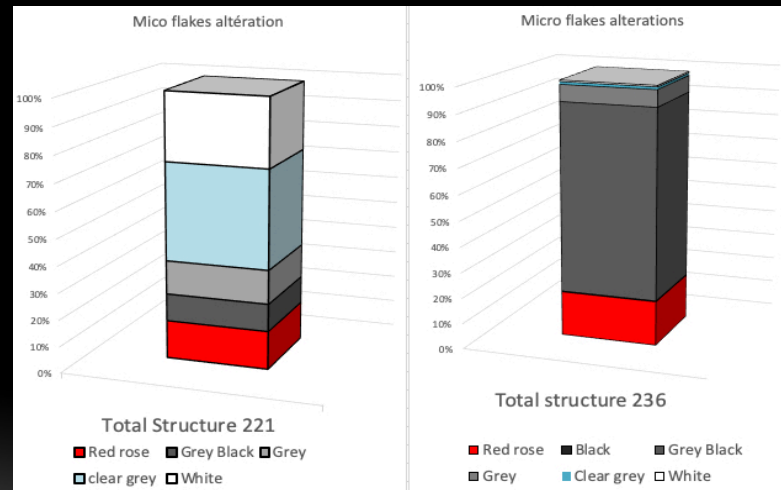
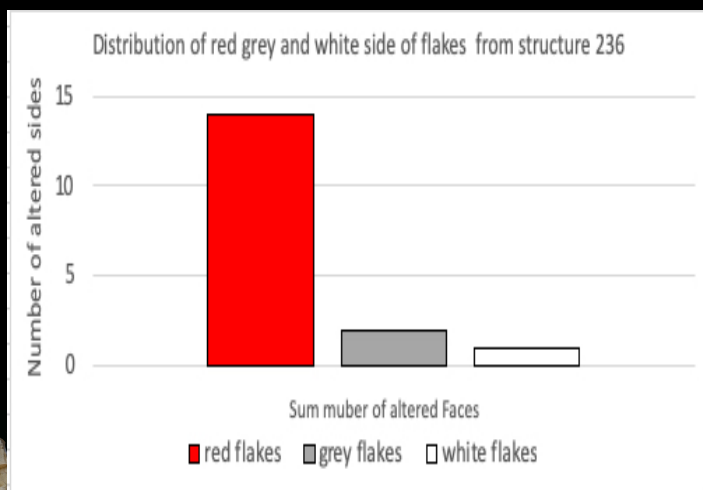
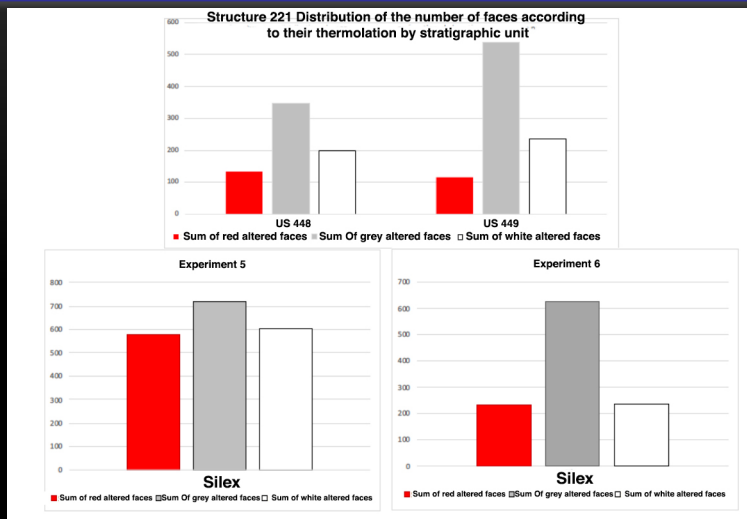
Towards a history of fire: Rebuild to understand

Louviers Site «Zac Cote de la Justice » the mode of functioning of the Heated stones fires structures



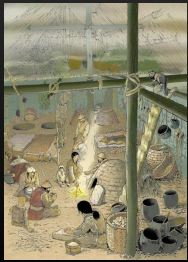
Heated stones fires structures

- Study of heating stone combustion structures
- Analysis of thermal alteration of rocks And sediments



Towards a history of fire: research to analyze, interpret and build

Louviers Site «Zac Cote de la Justice » : Molecular analyses of Alkanes

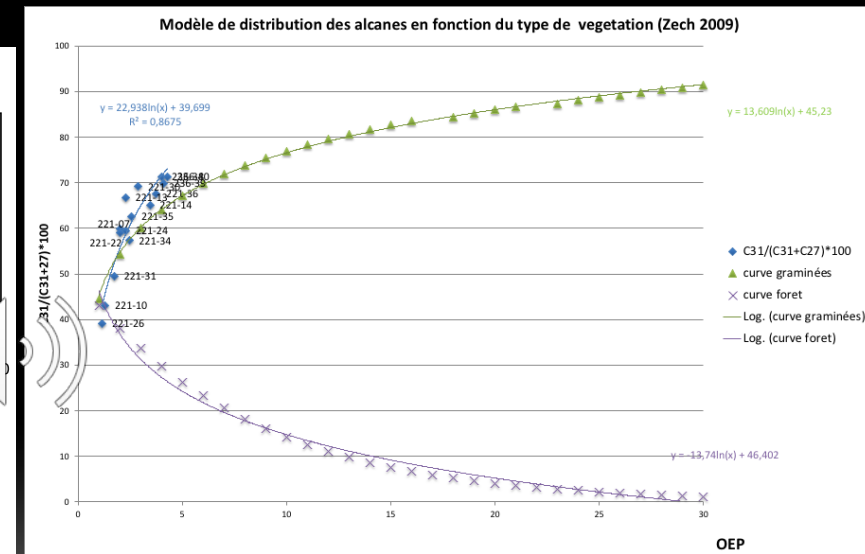
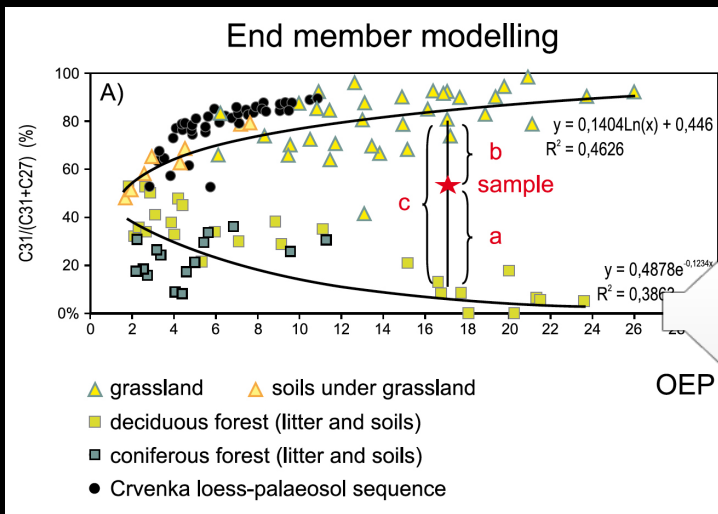
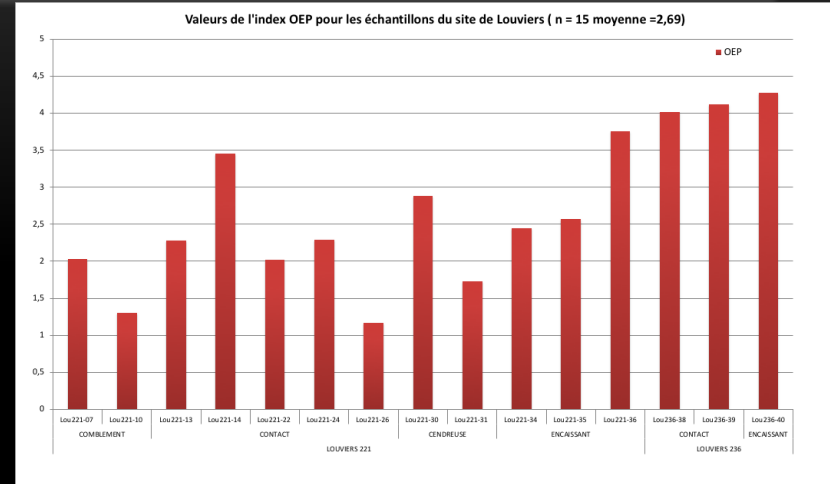
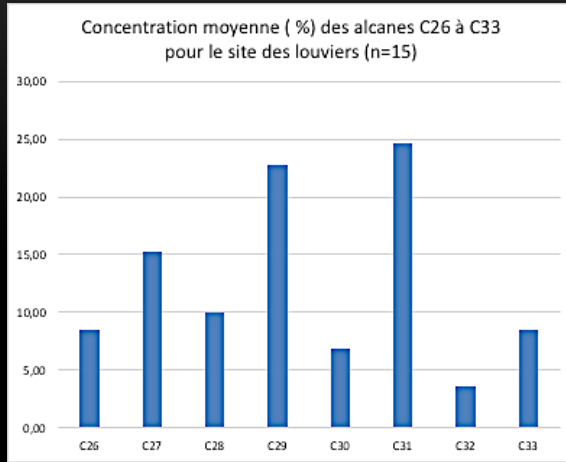


•Study of heating stone combustion structures

•Chemical molecular analysis

•Presence of lipids hydrocarbons fats grasses and residues related to the fuels used

Heated stones fires structures

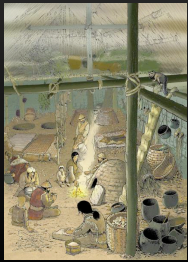


✓ analysis of the origin of n-alkanes from the Louviers site using the distribution model for n-Alkanes C26 to C33 (according to Zech et al. 2009) Considering index $C31 / (C31+C27) \%$ and values of the OEP index for the studied samples.



Towards a history of fire: research to analyze, interpret and build

The site of Louviers «Zac Cote de la Justice»: molecular analysis of short and long Alkanes CPI and OEP values related with temperatures from sediments and heated flints

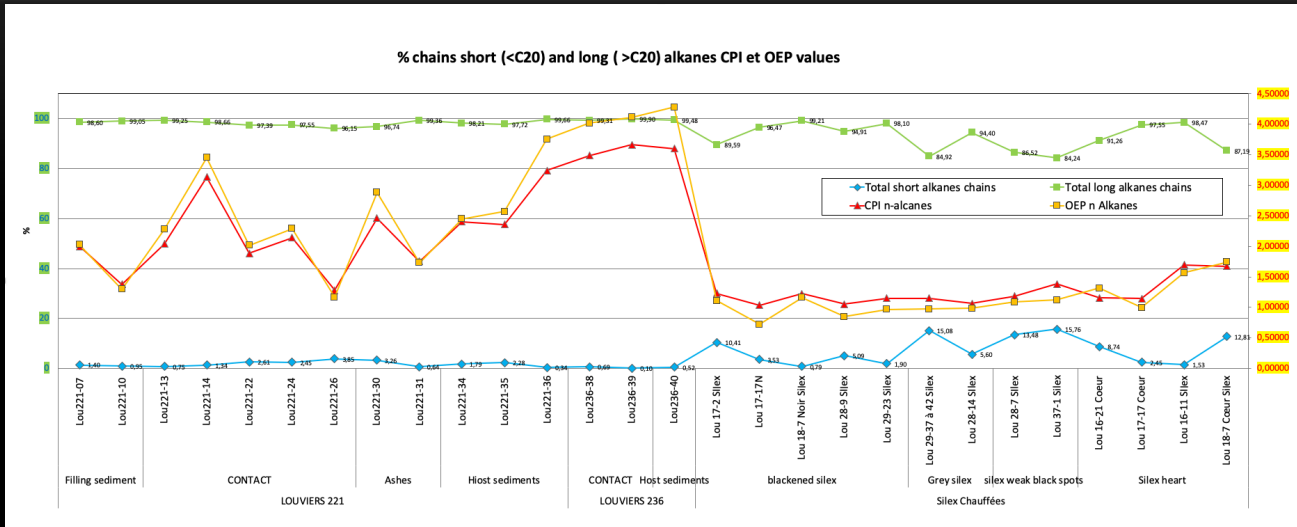


• Study of heating stone combustion structures

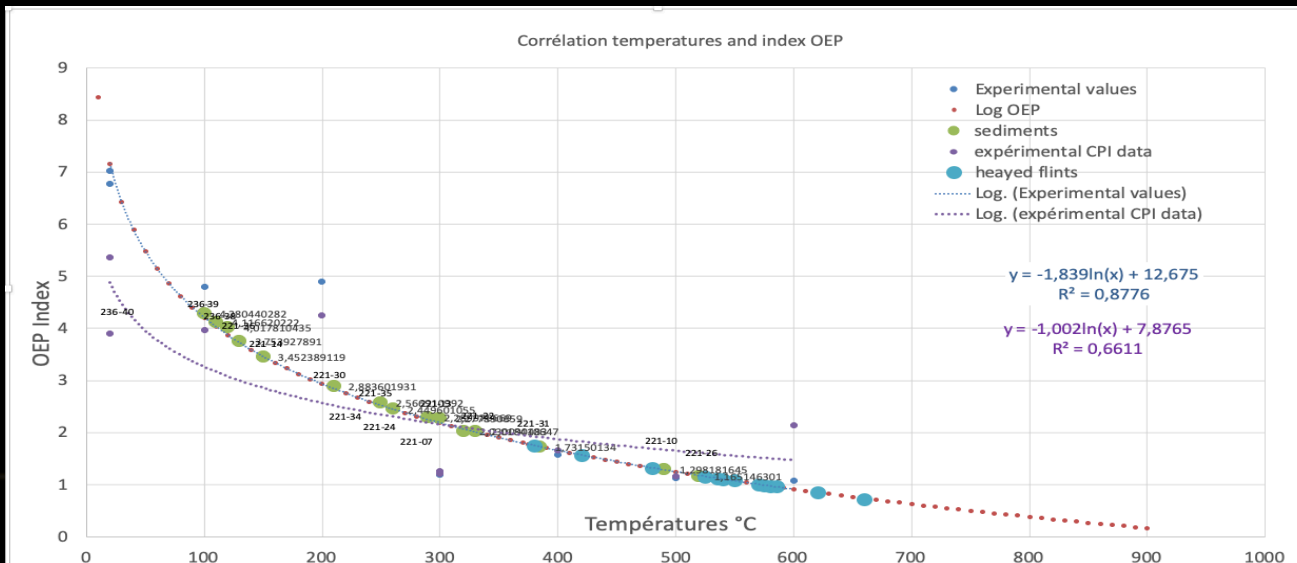
• Molecular Analysis of sediments and silex

• Determination of temperatures of exposition of samples

• Silex more heated than sediments



✓ % of short and long alkanes from samples from sediment from structures layers and heated flints



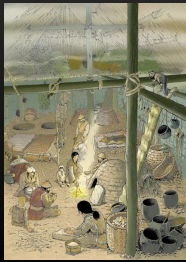
✓ Relation between OEP and CPI values of alkanes samples from sediments, flints, and experimental values

Heated stones fires structures

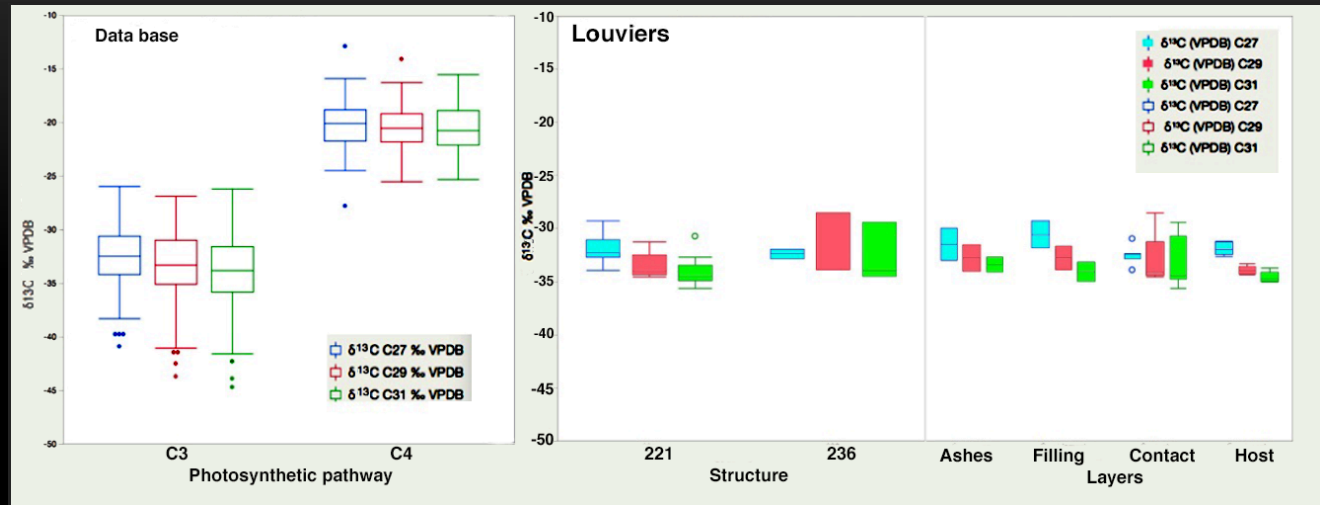


Towards a history of fire: research to analyze, interpret and build

The site of Louviers «Zac Cote de la Justice» isotopic analysis of alkanes C27, C29 and C31

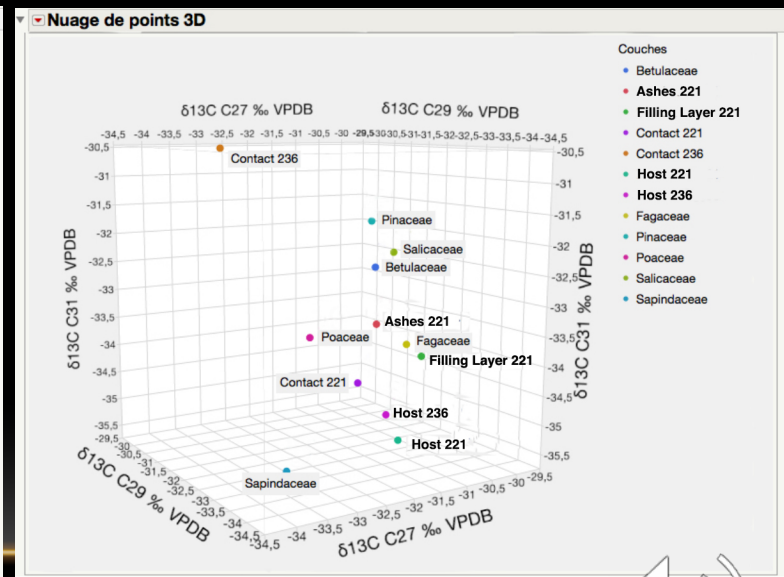
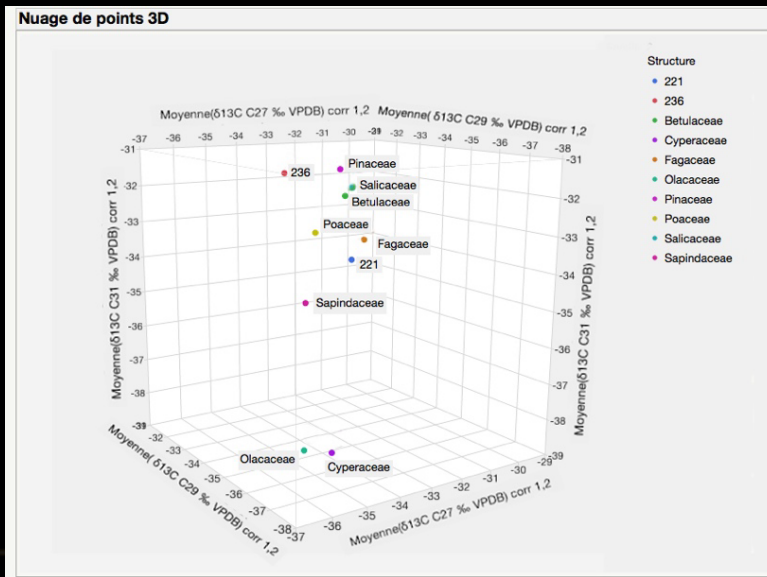


✓ Comparison of alkane isotope values from the Louviers site with our database compiling values for 457 plants.



Heated stones fires structures

- Study of heating stone combustion structures
- Molecular $\delta^{13}\text{C}$ isotopic analysis of C27, C29 and C31 alkanes
- Presence of fat lipids from C3 plants
- With some differences between the analysed structures and the different samples and layers of analysis

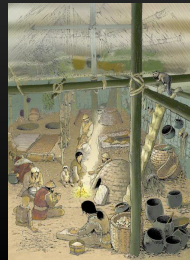


✓ 3D point cloud of the $\delta^{13}\text{C}$ isotopic values of alkanes as a function of the structures and layers of the Louviers site in relation to the families of C3 plants



Towards a history of fire: research to analyze, interpret and build

Louviers site «Zac Cote de la Justice » : palynological and anthracological data



	Taxon - sampling code	ST39- US 79	ST221 -US 450	ST236-US 457
Pollens	<i>Pynus silvestris</i>	0	1	0
	<i>Corylus</i>	0	1	0
	POACEAE	0	2	0
	CICHHORIODEAE	0	2	0
	JUNCAEEAE	0	0	1
	CYPERACEAE	0	2	0
	Lemma	0	2	2
Spores	Monoletic spores	0	0	3
Non-pollen	Hyaline microrestes -Hdv -182-or TM388	0	4	0
	Phragmospores-HDV 79	1	0	0
	undetermined	4	0	3
	SUM. Pollen (Base Sum)	0	10	3
	SUM Spore-pollen	0	10	6
	CONC. ABS Pollen (nb/cm 3)	0	671	186
	CONC. ABS Pollen and spores (nb/cm 3)	0	671	372

Table 1: Data account of pollens and spores determined in each of the 3 samples tested. The shaded values correspond to pollen sums, spore-pollen sums and for the last two lines to absolute concentrations of pollens and spores + pollens. Absolute concentrations are expressed as the number of grains per volume (mL) of sediment (Gaudin 2019b).

• Study of heating stone combustion structures

• Anthracological and Palynological Analysis

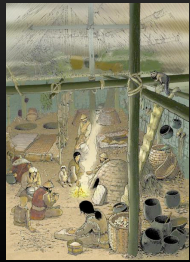
Samples				Charred remains			Other remains
Louviers	221	1/4 SE	H2	448	13	Absence of organic macro remains	gravel
Louviers	221	1/4 NW		448	16	1 seed ; 1 undeterminable charcoal, 1 charcoal of <i>Quercus/Castanea sp.</i> (Length: 2 mm); 2 charcoals of <i>Fagus</i> (Length< 2 mm)	gravel
Louviers	221	1/4 NE		448	17	10 charcoals of dimension < to 4 mm : 5 undeterminable charcoals, 1 charcoal of <i>Quercus sp./Castanea sp.</i> , 1 charcoal of <i>Fagus</i>	gravel
Louviers	221	1/4 SW		449	26	Absence of organic macro remains	gravel
Louviers	221	1/4 SW	N2	449	24	Absence of organic macro remains	gravel
Louviers	221	1/4 NE		449	28	1 charcoal of <i>Fagus</i> length 4 mm, 24 charcoal of dimension < to 3 mm	gravel
Louviers	221	1/4 NW		449	29	5 charcoals de <i>Quercus sp./Castanea sp.</i> of dimension < 4 mm, 2 undeterminable charcoals of dimension < 4 mm	gravel
Louviers	221	1/4 NE		449	27	1 vegetable remainder (seed?); 1 vegetable remainder (seed?, Length: 3 mm)	gravel
Louviers	221	1/4 NW	G2	450	30	1 fragment of bark (L: 2 mm)	gravel
Louviers	221	1/4 SE	R2	450	31	3 undeterminable remains of dimension < to 4 mm	
Louviers	236	1/2 S	5.3	US2	40	4 charcoals of <i>Quercus Sp./Castanea sp.</i> of dimension < to 2 mm	gravel

Table 2: Results of preliminary anthracological analyses of samples from structures 221 and 236 at the Louviers site (D. Aoustin with modifications)

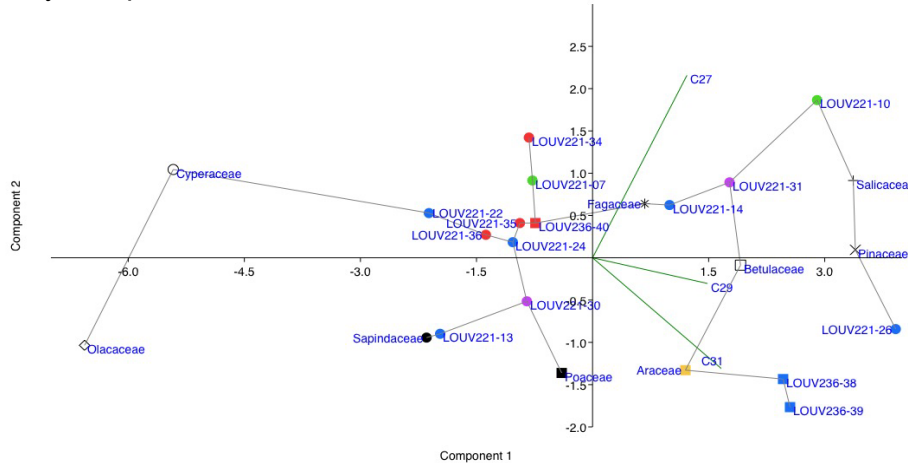


Towards a history of fire: research to analyze, interpret and build

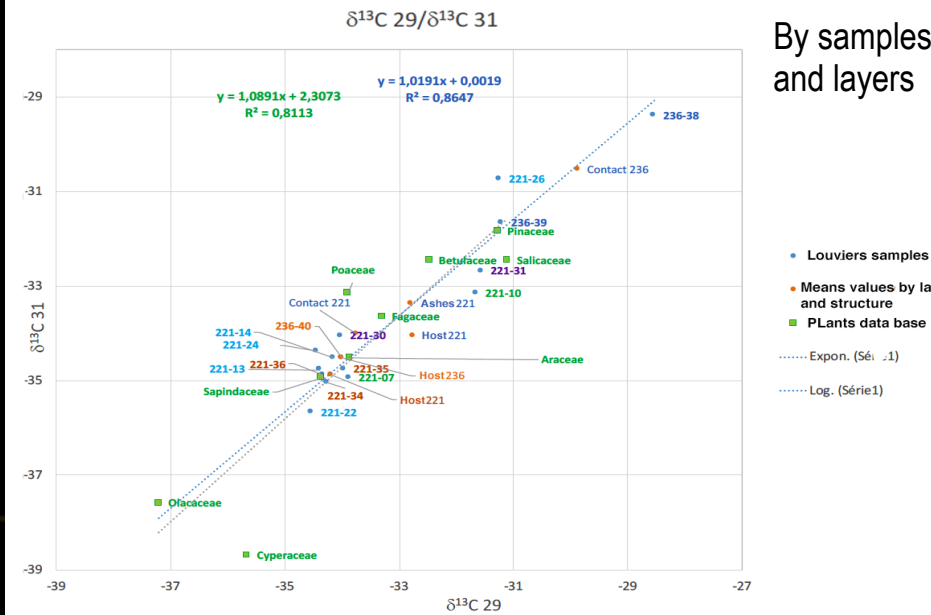
The site of Louviers «Zac Cote de la Justice»: molecular isotopic analysis of hydrocarbon



By samples



✓ Factor analysis of the means of the $\delta^{13}\text{C}$ isotopic ratios of C27 C29 and C31 alkanes per sample and stratigraphic layer within the structures of the site of Louviers in comparison with average values of the families of plants C3 and CAM from our database that may be present on the site.



By samples and layers

✓ Bi-variate analysis of the $\delta^{13}\text{C}$ isotopic values of alkanes C29 and C31 from samples from the site of the Louviers and families of plants C3 and CAM that may be on the site.

Heated stones fires structures

- Study of heating stone combustion structures

- Molecular isotopic analysis of C27, C29 and C31 alkanes

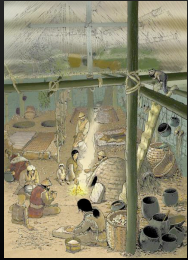
- Presence of fat lipids from C3 and CAM plants

With some differences between the analyzed structures and the different samples and layers of analysis



Towards a history of fire: research to analyze, interpret and build

Le site de Louviers «Zac Cote de la Justice » : approximation chimio-isotopique exploratoire des processus de formation des matières organiques des structures de combustion du site de Louviers

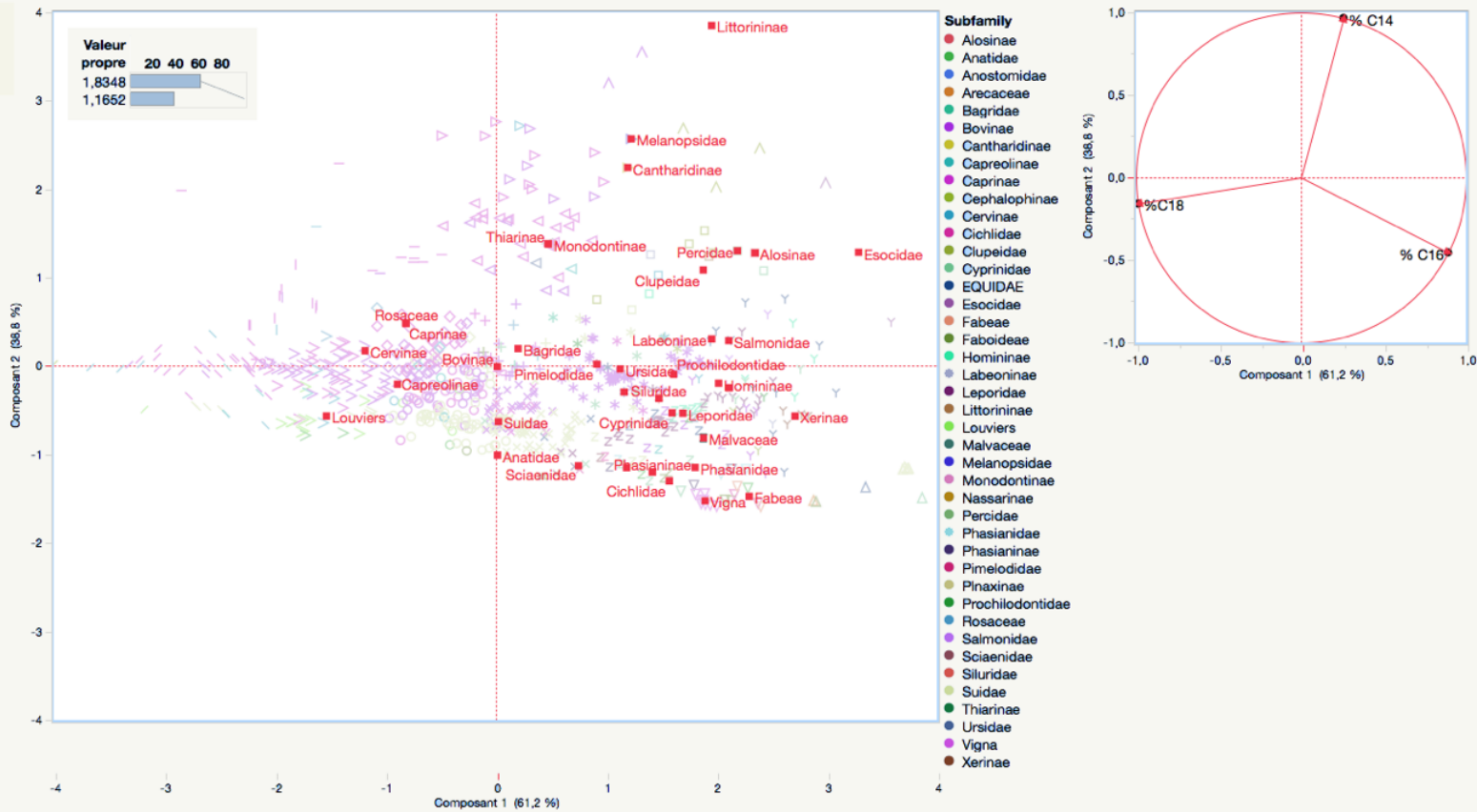


Heated stones fires structures

- Study of heating stone combustion structures
- Molecular analysis of C14, C16, and C18 fatty acids by families
- Presence of fat lipids from herbivores

Composantes principales calculées avec les corrélations

Graphiques de résumé

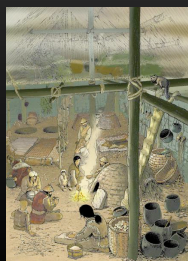


- ✓ Analysis by PCR main components of C14/C16/C18 saturated acids in samples (n=1004) from the site of Louviers
- ✓ and different species of families and sub-families of animals and plants from our database



Towards a history of fire: research to analyze, interpret and build

The site of Louviers «Zac Cote de la Justice»: molecular isotopic analysis of fatty acids

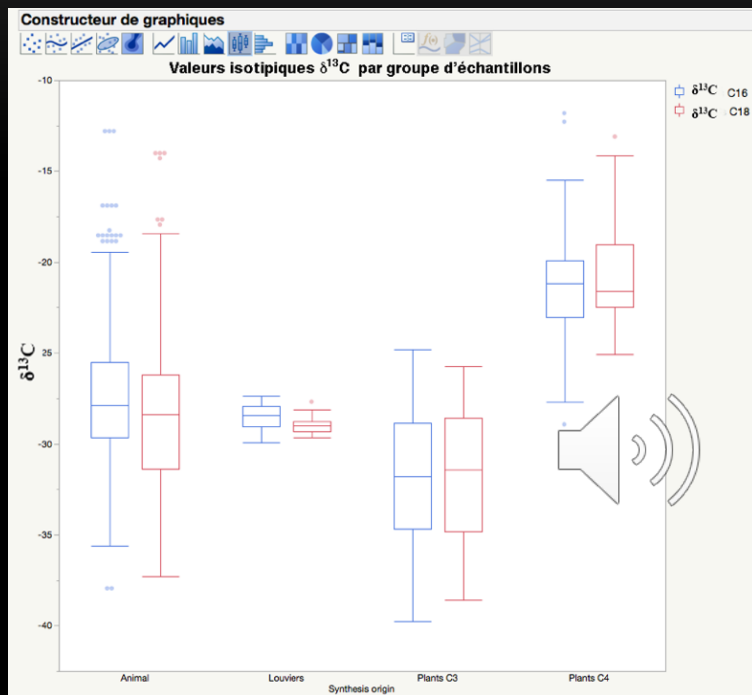


• Study of heating stone combustion structures

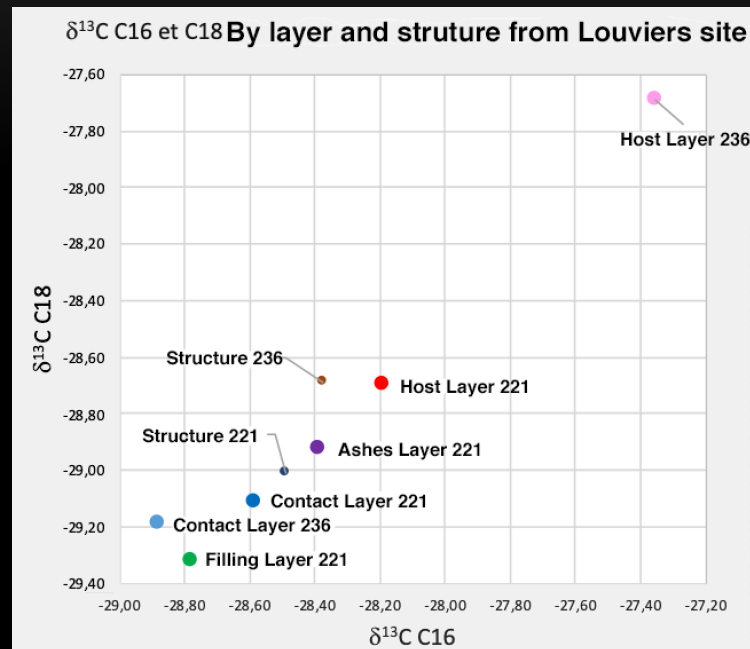
• $\delta^{13}\text{C}$ molecular isotopic analysis of C16 and C18 fatty acids

• Presence of animal fat lipids

• With some differences between the analysed structures and the different analysis layers



✓ Comparison of $\delta^{13}\text{C}$ isotopic values of saturated fatty acids C16 C18 from Louviers site with our database compiling the values of 572 animal, 173 plants C3 and 26 plants C4 samples.

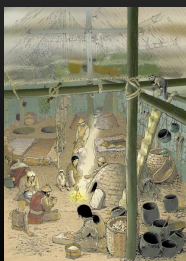


✓ Bi-variate analysis of the average isotopic values of $\delta^{13}\text{C}$ for saturated fatty acids C16, C18, by layer and structure of samples from the Louviers site



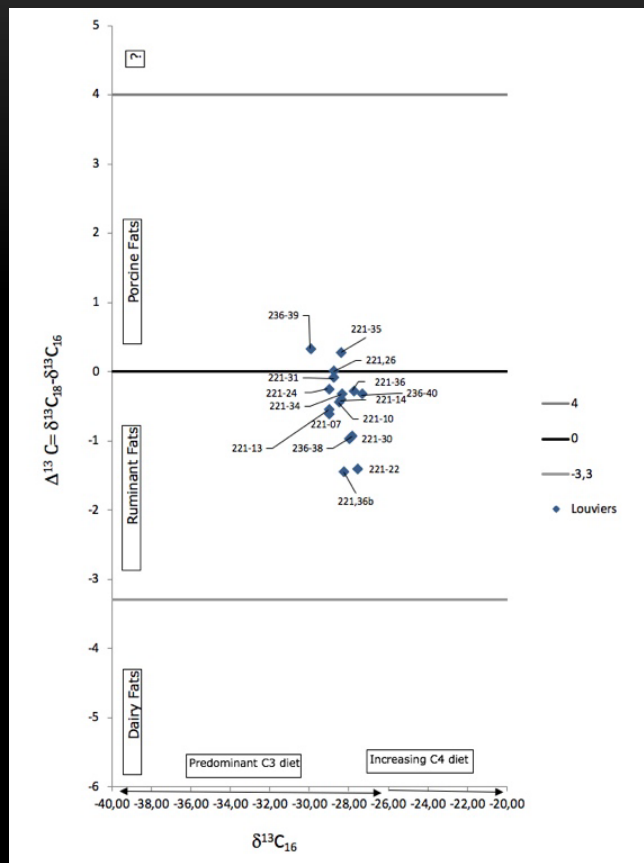
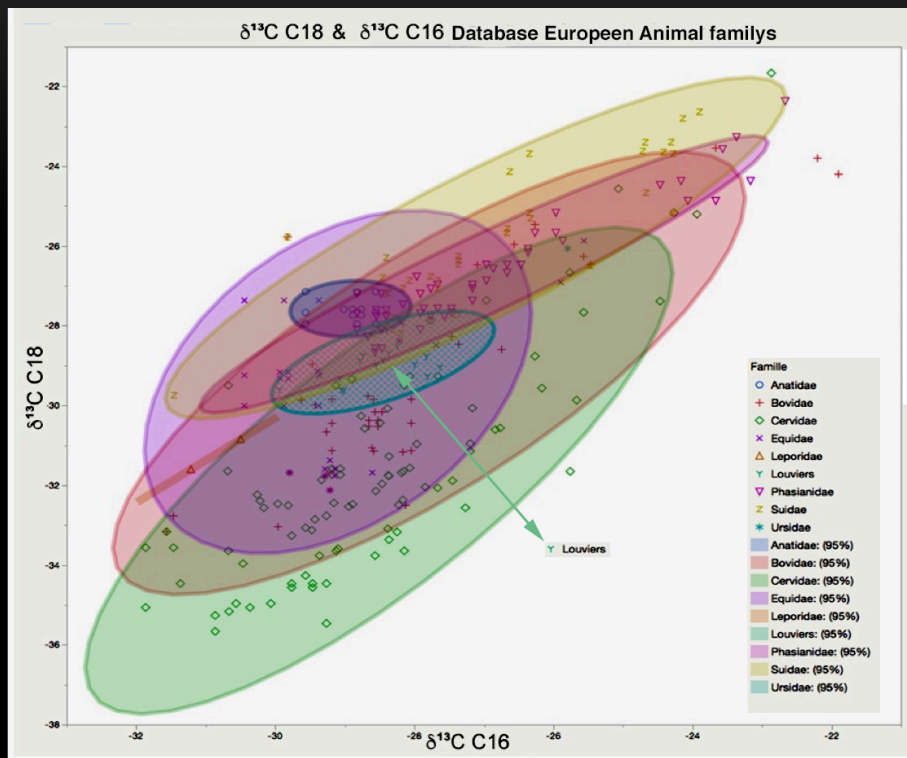
Heated stones fires structures





Heated stones fires structures

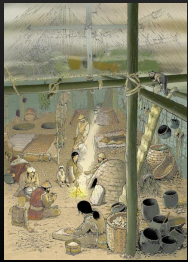
✓ isotopic values $\delta^{13}\text{C}$ of saturated fatty acids of Louviers samples and the animals from our own database complemented by bibliographic data



✓ Isotopic $\Delta^{13}\text{C}$ and $\delta^{13}\text{C}$ C16 ‰ from samples of Louviers site following Copley method (2003, 2005 a et b et March 2013 et 2018)



Towards a history of fire: research to analyze, interpret and build



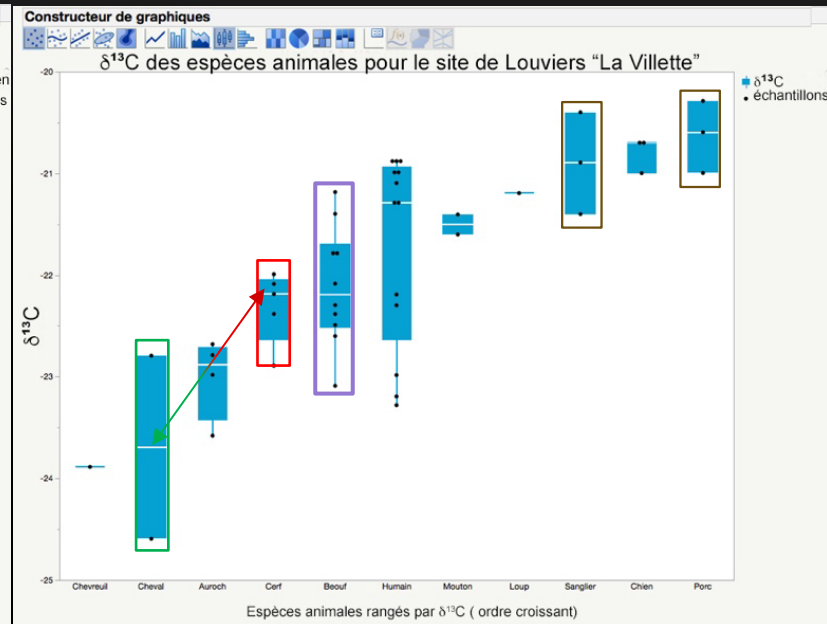
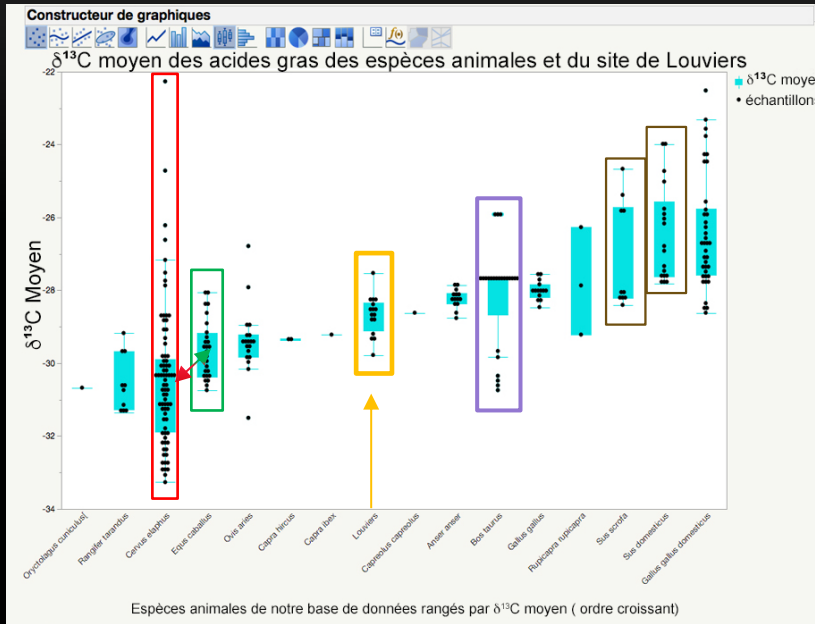
The site of Louviers «Zac Cote de la Justice»: molecular isotopic analysis of fatty acids and collagen

• Study of heating stone combustion structures

• Molecular isotopic analysis of saturated fatty acids C16 and C18

• Presence of animal fat lipids

• Collagen isotope analysis

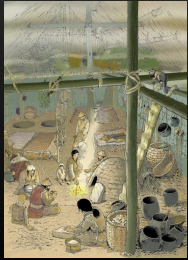


✓ Boxed graph of the mean isotopic values $\delta^{13}\text{C}$ (average $\delta^{13}\text{C}$ C16 and $\delta^{13}\text{C}$ C18) of the animals in our database and archaeological samples from the Louviers site ranged by ascending order of the different animal species

✓ Boxed graphs of isotopic values $\delta^{13}\text{C}$ ranged by ascending order of the different animal species identified in the northern hunting assemblage of Louviers La Villette (Giligny et al 2005)



The site of Louviers «Zac Cote de la Justice»: molecular analysis of short and long Alkanes CPI and OEP values related with temperatures from sediments and heated flints



Conclusion

Our results show that the structure 221 was used for cooking but not for combustion, while the structure 236 was used for combustion and cooking at lower temperatures, and that these structures do not show the same traces of cooking plants and animal even it could be considered similar morphologically.

This first application of experimental and analytical study of heated flints and soils and the isotopic analysis of alkanes and fatty acids open the possibility of completing molecular analyses, enriching and supplementing their conclusions concerning their vegetal and animal origin. This create new perspectives for this analysis analyses showing the correlations of the results between the palynological and anthracological approach's.

Finally we can demonstrate and reconstruct the mode of function and utilisation of these structures Indicating the needs for an expansion of our reference base from the study of bone remains concerning the different periods and local regions analysed for an optimization of interpretations of the origin of lipids of animal origin.

•Study of heating stone combustion structures

•Molecular Analysis of sediments and silex

•Determination of temperatures of exposition of samples

•Silex more heated than sediments

