



HAL
open science

Radiocarbon dating of iron reinforcements of Notre-Dame de Paris cathedral

Mathilde Bernard, Lucile Beck, Emmanuelle Delque-Količ, Maxime L'Héritier,
Aurélia Azéma, Philippe Dillmann

► **To cite this version:**

Mathilde Bernard, Lucile Beck, Emmanuelle Delque-Količ, Maxime L'Héritier, Aurélia Azéma, et al.. Radiocarbon dating of iron reinforcements of Notre-Dame de Paris cathedral. Joint ICTP-IAEA Advanced Workshop on Accelerator Mass Spectrometry Radiocarbon Dating for Heritage and Forensic Sciences, May 2023, Trieste, Italy. hal-04270282

HAL Id: hal-04270282

<https://hal.science/hal-04270282>

Submitted on 3 Nov 2023

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Radiocarbon dating of iron reinforcements of Notre-Dame de Paris cathedral

Mathilde Bernard¹, Lucile Beck², Emmanuelle Delqué-Kolic², Maxime L'Héritier³, Aurélia Azéma⁴, Philippe Dillmann¹

¹ LAPA, IRAMAT UMR7065, NIMBE UMR3685, Université Paris-Saclay, CEA/CNRS, France
² LMC14, LSCE-IPSL, CNRS/CEA/UVSQ, France

³ Université Paris 8, ArScAn UMR7041, CNRS, France
⁴ LRMH, CRC UAR3224, MNHN, France

Context

Iron reinforcements of Notre-Dame de Paris cathedral are a source of data for the interpretation of gothic architecture. Radiocarbon dating of these metallic armatures can provide information on the chronology of the building and reveal potential recycling during restoration phases. In addition, this method coupled with archaeometallurgical analyses can highlight which roles iron played in the monument's construction.

Radiocarbon dating was performed on six cramps (tribunes and upper walls) and on two ancient tie-rods of the clerestory windows.

Radiocarbon dating of iron

Iron ore reduction

- Wood charcoal + iron ore

Metallographic observations



Sampling in the most carburized areas (cementite phase Fe₃C)

Sample sealed in quartz tube along with an excess of CuO and silver wire

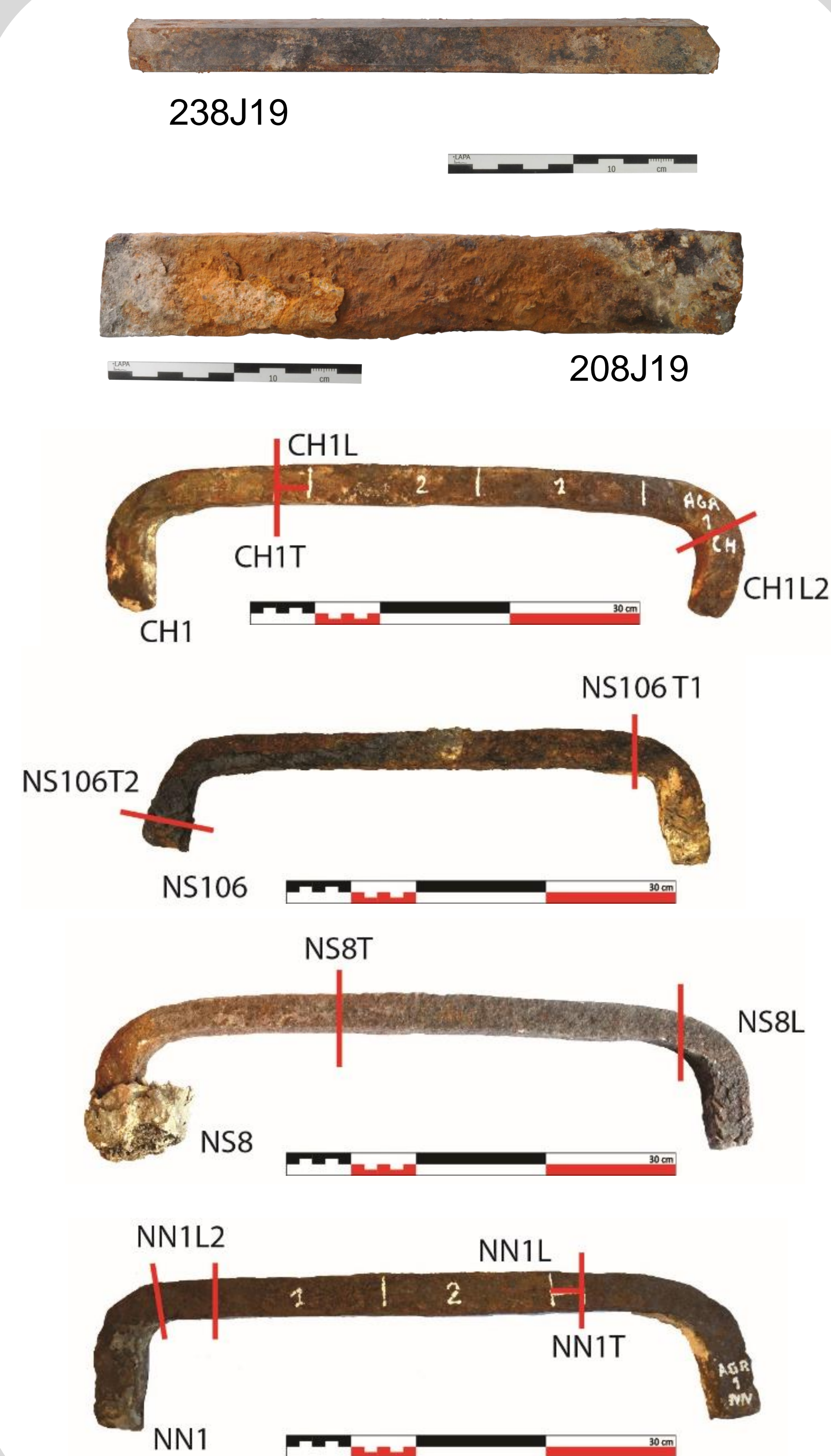
- CuO/Fe ratio = 5
- 850°C for 5 h

Graphitization

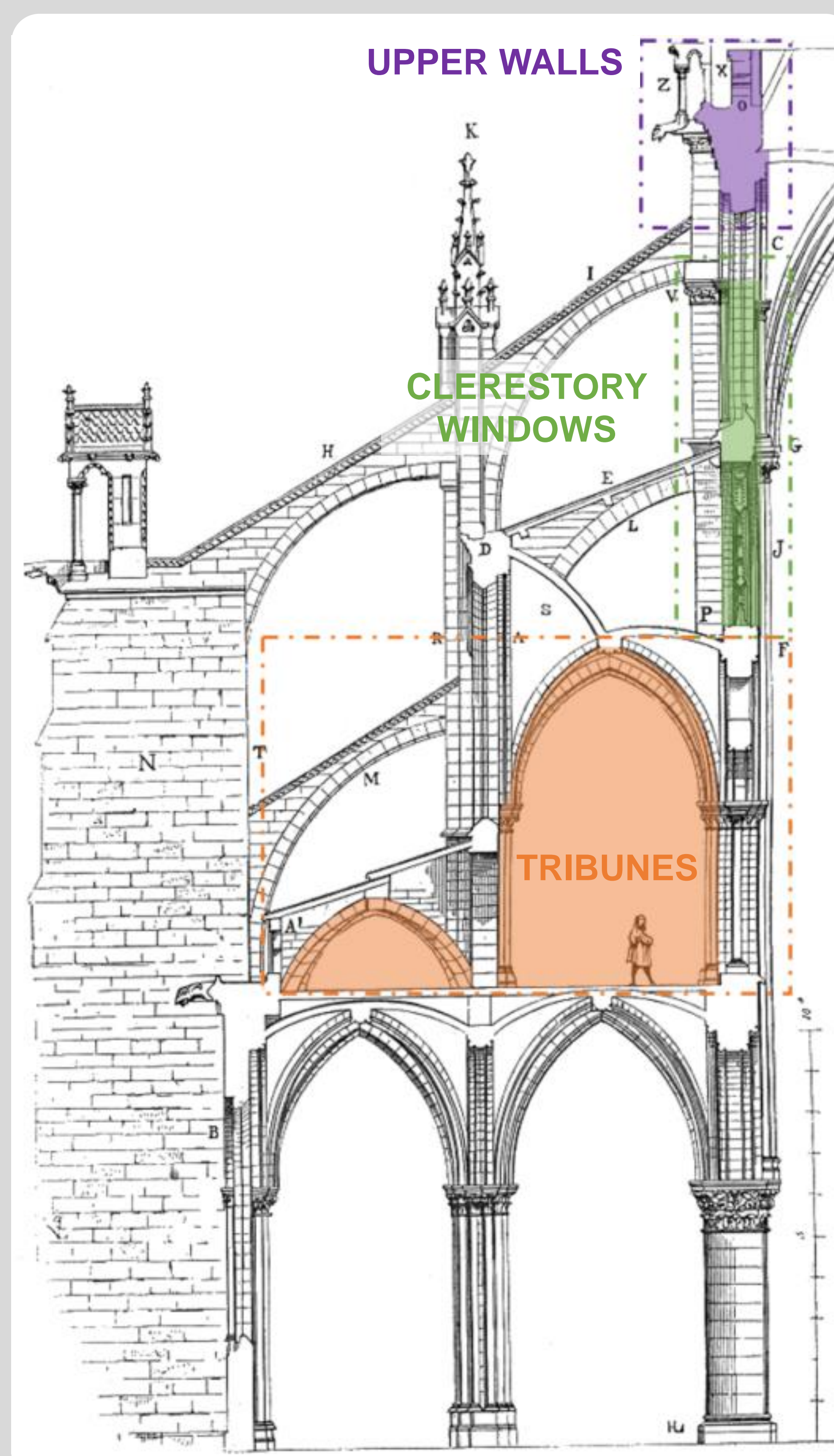
Radiocarbon measurement using AMS (ARTEMIS, LMC14, Saclay)

Calibration: IntCal20 Northern Hemisphere radiocarbon age calibration curve – OxCal software

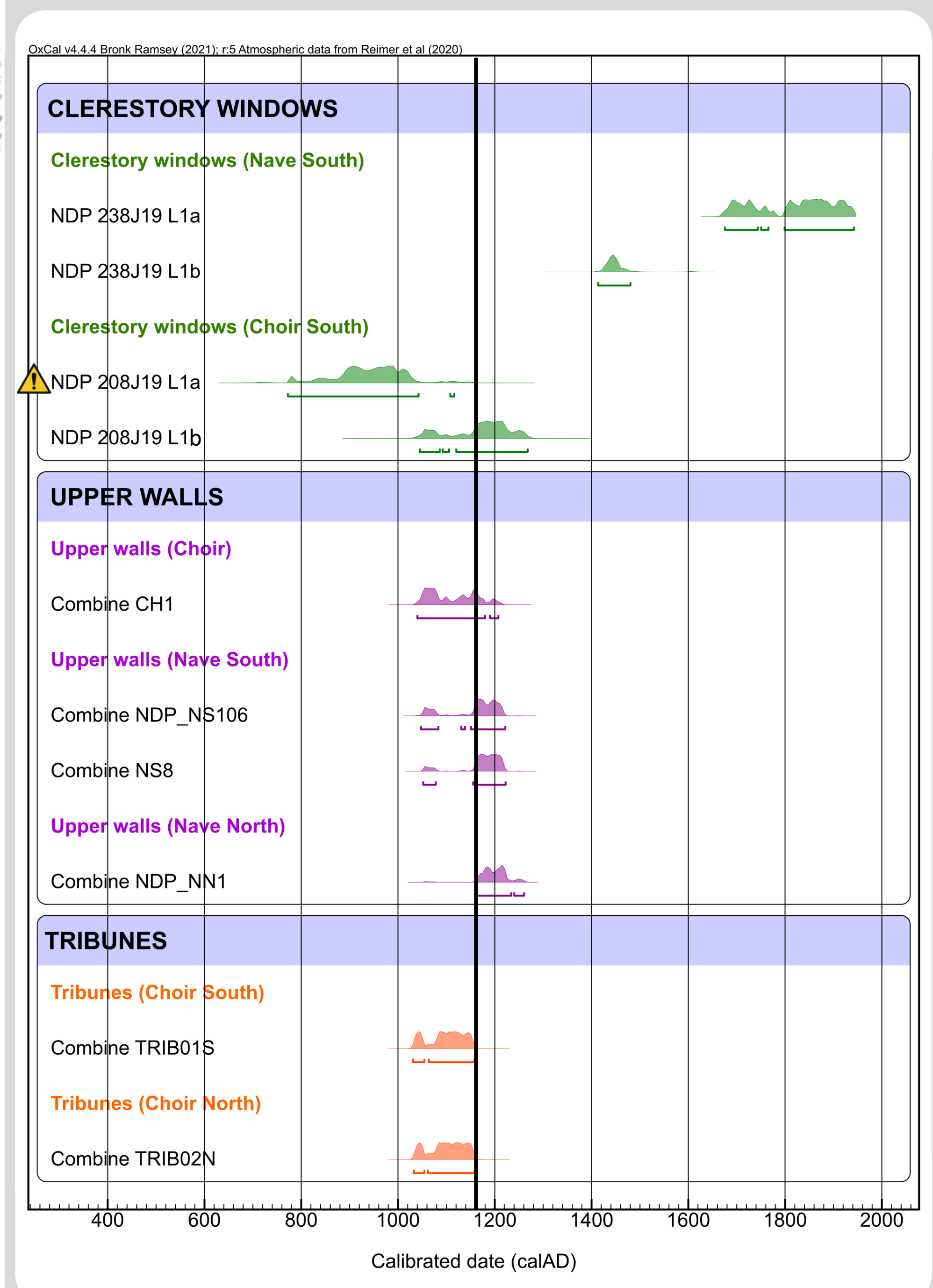
Studied iron reinforcements



Results



Cross section of Notre-Dame de Paris cathedral, *Dictionnaire raisonné de l'architecture française du XIe au XVIe siècle*, E. Viollet-le-Duc, Édition BANCE – MOREL, 1854-1868



▲ Low mass of carbon collected : m = 0,12 mg

Conclusion

❖ The results concerning the cramps show that these samples are contemporaneous with the construction phases of the cathedral in the middle of the 12th or beginning of the 13th century. The two cramps of the tribunes are older than those coming from the upper walls. It proves that the builders implemented these iron armatures of the tribunes in the earliest phases of construction, most probably in the early 1160s. So far, these series of cramps are the earliest known example of iron armatures used in the initial design of a Gothic monument. However, the rows of cramps of the upper walls were dated from the early 13th century at the latest. It coincides with the dating of the 13th century framework, indicating that the erection of the wall and the installation of the cramps occurred shortly before the completion of the framework.

❖ The radiocarbon study of clerestory windows tie-rods samples show that one of them is contemporary with the reconstruction phase of 1225 mentioned by E. Viollet-le-Duc. The second sample seems to be from a later early modern or modern restoration phase.

Outlook

Radiocarbon analyses of the samples presented in this poster give a first vision of the use of these metallic armatures in the construction of Notre-Dame de Paris cathedral. Other samples will be analyzed in the upcoming months, including cramps from the choir upper walls, for a better understanding of this Gothic monument.

Ref : [1] Leroy et al., 2015, Consolidation or initial design? Radiocarbon dating of ancient iron alloys sheds light on the reinforcements of French Gothic Cathedrals, *Journal of Archaeological Science*, 44, 21-35 ; [2] L'Héritier et al., 2023, Notre-Dame de Paris: The first iron lady? Archaeometallurgical study and dating of the Parisian cathedral iron reinforcements, *Plos ONE*, 18(3): e0280945 ; [3] *Dictionnaire raisonné de l'architecture française du XIe au XVIe siècle*, Eugène Viollet-le-Duc, Édition BANCE – MOREL, 1854-1868