

0000000002 - EXCALIBUR

SCHADOC: Research and training doctoral programme

SCHADOC: First call doctoral fellowships

Application Reference Number [Application ID] : 0000000002

Project Acronym: EXCALIBUR

Project title EXploring ancient diet by using dental CALculus In archaeological BURial context

thesis supervisor: Dr Goude Gwenaëlle UMR 7269 LAMPEA, Aix-Marseille Univ. France

thesis co-supervisor: Dr Power Robert C. School of Archaeology, University College Dublin, Dublin, Ireland

International partner 1: Dr Salazar García Domingo C. Department of Prehistory, Archaeology and Ancient History University of Valencia Spain

International partner 2: Dr Bouby Laurent Institute of Evolutionary Science of Montpellier; Dynamics of biodiversity, anthropoecology team - Archaeobotany facility University of Montpellier, France

Non-academic partner (socio-economic or cultural): INRAP, Institut national de recherches archéologiques préventives. legal representative Professor Garcia Dominique

0000000002 - EXCALIBUR

1. EXCELLENCE (4 pages max)

1.1. Pre-proposal's context, positioning and objective(s)

The EXCALIBUR (EXploring ancient diet by using dental CALculus In archaeological BURial context) project proposes an exploratory work to identify the potential of a biological matrix, the dental calculus, mineralised dental plaque, **to study ancient diet and to make inferences about social identities and environmental adaptations**. Dental calculus, which is often present on archaeological human and animal teeth, can provide a unique source of past (diet, environment, health and social interactions) and present information (burial environment, state of preservation, assessment of bioarchaeological potential). This project proposes to test current analytical methods and combine them to advance their potential for **multidisciplinary, semi-invasive work on sensitive remains**. Archaeological human remains are an important reservoir of biological heritage, which is used to study diet, mobility, the environment and social or economic practices from the past. However, osteological material (bone, teeth) is finite and may prove too fragile or limited to sample for analysis and preservation. So-called “para-osteological” material, such as dental calculus, is less abundant than the teeth themselves, but when present, it may prove a promising alternative study option at least for two main reasons: (1) it contains a **body of environmental information that is unidentifiable on the rest of the human body** (e.g. entrapment of plant remains, fibres, insects in contact with the oral cavity); (2) it preserves **proteins and other molecules that accumulate throughout an individual's life**, providing additional information on bone and dental tissue. The study of the microremains of dental calculus and some food proteins trapped is a key element in the study of dental tissue.

The EXCALIBUR project builds on 15 years of research, specifically drawing from the work of the supervisors and consortium members on ancient diets (University of Valencia, ISEM, INRAP; see partnership document). Several key issues are addressed:

- 1) How to enhance the identification of food remains in dental calculus?
- 2) How to interpret the data on dental calculus with other proxies commonly used in bioarchaeology (archaeobotany studies) and anthropology (biogeochemical studies)?
- 3) Is the dental calculus a good proxy to differentiate regional/cultural/social patterns (as for example providing info on male vs. female food consumption diversity)?
- 4) How to detect specific foods as acorn and corn, two markers that identify either geographical and social origins in the 18th and 19th centuries (eg. Marache and Meyzie 2016), or the impact of plant products in the diet of prehistoric times (eg. Bouby et al. 2024)?

The research community has recently expressed interest in dental calculus on the one hand to overcome or complement problems of conservation of other tissues (i.e. collagen in particular) and on the other to provide a biological indicator on a site or population scale rather than on an individual scale (cf. Salazar-Garcia et al. 2023). This review (ibid.) as well as other studies (eg. Salazar-Garcia et al. 2014; Eerkens et al. 2014) shows, on the one hand, the difference of dietary information between biological matrices (i.e. collagen vs. calculus) and, on the other hand, the need for development in the use of isotopic markers, well integrated into international multidisciplinary projects so far not applied to archaeological dental calculus. **Identifying food consumption from archaeological human and animal remains requires diverse techniques and proxies**. Dental calculus microremain analysis has proven to be a promising method, though it remains underrepresented in bioarchaeological studies, especially in France. The combined study of the isotopic compositions of bone/teeth remains and dental calculus proteins and trapped microremains has been developed in archaeological and environmental sciences for around fifteen years. **In France, the development of such combined work has advanced through the collaboration of the two thesis supervisors** (RP, GG) in several past (Fondation pour la Recherche Médicale Danone Foundation 2016-2017; Goude et al. 2019) and current (ANR

0000000002 - **EXCALIBUR**

WomenSOFar 2022-2026 ANR-21-CE03-0008) research projects. As an example, the dental calculus found on the teeth of Neolithic coastal populations has been used to directly identify the consumption of wild plants by early agropastoralists (Power in Goude et al. 2020). Despite several analyses published in international journals, it is still under-developed and deserves new tests using well-documented archaeological contexts (as available in WomenSOFar and Orthez). The integration of microremains with isotopes in the narrative of dietary reconstructions is far from being one of the methods usually used in archaeology, even though this combined approach has proved highly successful in international studies on Prehistoric populations (Salazar-Garcia, Power et al. 2021; 2022). **The challenge of EXCALIBUR is to fill a chronological and geographical gap in the study of past diets within an increasingly competitive European research context in terms of conservation and use of heritage archives.**

For the PhD project, the candidate will have to review the literature to understand the different routes by which dental calculus forms and calcify. Then, several technical steps will be carried out (fig. 1 below) that include:

- A) Optical microscope recording and **identification of dental calculus microremains** (as charcoal, phytolith, starch, diatoms, or food fragments like fish scale) from two sets of collections already acquired with authorization under the ANR WomenSOFar (n=53) and PCR Orthez 1814 (n=11) projects. This aspect will be complemented by work to advance recent progress in starch identification (Ahituv, Henry 2022) **on a machine learning protocol using ImageJ** (as seen in Power et al. 2015) to develop the identification of microremains at a larger scale to 1) increase the number of samples studied and 2) enable statistical processing of data.
- B) Establish a new methodology as part of an exploratory work on selected samples-individuals to specifically **provide guidelines for the identification** of acorn starch (prehistoric times) and corn starch (18th and 19th century) consumption as a regional marker. In this case, the PhD student and the supervisors/partners will create modern models of chemically and thermally altered cooked food/calculus exposed to these foods in laboratory conditions. If the results of this stage are very optimistic, a second batch of samples may be included (non-academic partner INRAP involved and ISEM) to extend the study to chronological periods not yet covered by this approach (as Bronze Age and Iron Age in Auvergne, Occitania and Pyrenees in France), particularly in regions where archaeobotanical studies have detected the use of acorn and other plants having undergone kitchen-related treatments (cf. Bouby 2014; Bouby et al. 2024).
- C) The **creation of a regional open access database to facilitate future studies in the contexts involved, and easily usable for field research** (in collaboration with non-academic partner INRAP; field and laboratory protocols easily handled by non-specialist colleagues).

The PhD candidate will also contribute to the scientific progress of the research programmes by 1) **documenting the gender/age-based food** differences during Prehistoric times (ANR WomenSOFar) and 2) **identifying regional food access** allowing to determine the geographical origin of 18th-19th soldiers discovered in southwestern France (PCR Orthez 1814, Dir. I. Souquet).

The project is innovative in that it uses material that has long been neglected in bioarchaeological studies (mainly studied to assess the sanitary conditions of ancient populations). It is also novel in terms of the technical and methodological efforts made by internationally recognized scientists in this field. Finally, it is innovative in the new dimension it proposes to the study of **dietary diversity: testing the plant world as a marker of culture**, whereas plants are often very difficult to find on sites and remain the “hidden part of the iceberg” of ancient diets.

0000000002 - EXCALIBUR

The project explores gender differences in food acquisition, building on findings from the ANR WomenSOFar programme and previous studies (e.g., Goude et al. 2020). Understanding the diversity of female and male food access is crucial for interpreting social interactions in prehistoric communities and reflects mobility patterns and patrilocality systems revealed through aDNA and isotopic analyse. The dental calculus studied in EXCALIBUR project come from individuals of different sex and age (including children; eg. Chaïd-Saoudi et al. 2025) for which stable isotopes and bone activity markers imply **sex-based patterns in mobility and diversity of food and physical activities** (stable isotope ex. Couvrat et al. 2024 and bone activity markers ex. Bédécarrats et al. 2024). The food identification in the dental calculus of these individuals will provide new insight into the variability of food acquisition and explain the possible difference in environmental use according to the place they come from and their social status.

EXCALIBUR

2025-2027



WP 1 - Microremains identification

- Optical microscopy
- Machine learning protocol
- Foods to target for exploratory studies (acorn, corn)



WP 2 – Gender and age impact on food consumption

- Cross-referencing of biological, isotopic and calculus data
- Establishing a model by environmental zone
- Women's mobility, social ages in prehistory and the identification of local soldiers

2027-2028



WP 4 – Outreach and open access deliverables

- Creation of a regional open access database for micro-remains identification directly usable by preventive archaeology colleagues
- Creation of a photo exhibition between art and science



WP 3 – PhD manuscript and Peer reviewed disseminations

- 1 article IF in international journal
- 1 article in Diamond Open Access journal
- 2 communications in international symposium

Supervisors
LAMPEA – Aix-Marseille Univ. France
UCD Dublin Ireland

Ac partners
Dpt Prehistory, Univ. Valencia Spain
ISEM Montpellier Univ. France

Non-ac partner
INRAP France



Figure 1. Diagram of the tasks to be carried out and the proposed consortium.

1.2. Interdisciplinary and intersectoral dimensions of the project

This doctoral project will be the first scientific co-supervising PhD collaboration between the two thesis supervisors, and it will be the **first exploration of such a subject for archaeological research in France**. However, the two laboratories, LAMPEA and School of Archaeology, have well-established partnerships on other past or current research projects and particularly they collaborate within the ANR WomenSOFar <https://womensofar.hypotheses.org/>, they already have worked together at the international level (ex. Goude et al. 2019; Jovanovic et al. 2021).

The PhD project EXCALIBUR will take place in two main institutions, in France and in Ireland: UMR 7269 LAMPEA (AMU, CNRS, MC, INRAP) (France) and the School of Archaeology of the University College Dublin (Ireland). Moreover, the co-tutoring and the project consortium involves other countries and experts involved in the study of past diet particularly at the Department of Prehistory, Archaeology

0000000002 - **EXCALIBUR**

and Ancient History of the University of Valencia (Spain), the Institute of Evolutionary Science of Montpellier (France) and a non-academic partner INRAP (cf. partnership document). The methodological development expected within this PhD project will also benefit the different laboratories in this partnership and will allow realizing skill transfers in different countries (France, Ireland, Spain) and among researchers, increasing quickly the panel of expertise of the INRAP. Within the MMSH laboratory and environment, the candidate will benefit from a number of technical resources enabling the PhD candidate to successfully complete the various stages of the project. The UMR LAMPEA offers support via the BOOST platform (Aix-Marseille University label; <https://lampea.cnrs.fr/spip.php?rubrique211>), which will enable a large part of the technical stages to be carried out in biogeochemistry and 2D/3D imaging. The ARKAIA institute (<https://institut-arkaia.univ-amu.fr/>) offers logistical and technical support, with access to several archaeological material preparation areas and office space.

0000000002 - EXCALIBUR

2. IMPACT (2 pages max)

2.1. Expected impact of the project on the candidate's career

The study of dental calculus is currently underdeveloped in archaeological research in France for past dietary reconstructions but **is increasingly integrated into European projects**. The project offers an opportunity to develop sought after expertise for both for field projects (INRAP, Ministry of Culture) and in the international academic sector.

In addition, we offer to the doctoral student the opportunity to integrate into the Aix-Marseille University training programme by co-tutoring a Master 1 and then a Master 2, in order **to transfer skills and broaden research activities in the field of archaeological sciences** offered by the Aix-Marseille University training programme.

This mentoring opportunity will enrich the candidate's professional experience and enable him/her to position him/herself for various competitive examinations in the academic sector (teaching/research). Aix-Marseille University also offers doctoral students the chance to work as a monitor, an opportunity that candidates can seize to enhance their professional careers. It will also allow them to develop skills in publication of scientific papers as publication of 2-3 papers first author are envisaged.

This project will function as a springboard for a forthcoming ERC-2026-CoG application (PI R C Power, UCD; partnership LAMPEA), with a key component being a PhD studentship focused on exploring dental structure and layering through a range of innovative methods to understand the formation and temporal resolution of dental deposits. The research will use cutting-edge approaches, including novel isotopic analysis and synchrotron radiation micro-CT, to integrate archaeological and modern dental samples. Additionally, the ERC project in design will involve a clinical intervention study, where dental patients will use a mouthwash spiked with a stable isotope marker which is safe and inexpensive. This marker will allow us to map the chronology of dental calculus formation. The PhD candidate will play a central role in this research, gaining valuable experience that will directly contribute to the ERC application, ensuring the project's continuity and enhancing its multidisciplinary approach.

2.2. Expected impact for the thematic axis

The EXCALIBUR PhD project addresses the thematic axis "Societies and Cultures". The project proposes a new investigation into ancient food cultures, with particular emphasis on linking them to the social structures of the targeted populations and their geographical and chronological contexts. We aim to ascertain **cultural diversity** (how males and females eat according to their age and social status?) and **identity** (how to identify local from non-local soldiers by means of the consumption of specific foods such as corn in the south-west of France?).

The project will provide those involved in heritage preservation (INRAP, Regional Services of Archaeology, Museums) with new methodologies for **minimizing invasive analyses and increasing the gain of information on ancient foods** by using bioarchaeological remains. The importance of plants in the diet will be brought back to the fore, and a public exhibition to be built during the project (fig. 1) will **help people understand the importance of plant resources in ancient societies - societies that have enabled us to be where we are today**. The expected results on dietary diversity could be potentially **presented in public health fields, for a holistic approach to the management of patients with eating disorders** (ex. G. Goude 2023 - citizen science project under development, R. Power 2024 - The Power of Variety: Diet Diversity Food Demo & Expert Q&A"). The public events and dissemination will also **open up perspectives on how we might rethink the old crops and practices as possible adaptations today** (e.g. C4 plants cultivation in France; <https://www.sudouest.fr/lot-et->

0000000002 - EXCALIBUR

garonne/agnac/agriculture-en-lot-et-garonne-pourquoi-le-sorgho-gagne-du-terrain-1648485.php) in an environment highly impacted by climate change.

2.3. Dissemination, exploitation and communication activities planned

The Project is divided into four work packages (cf. fig. 1) with two dedicated to open access resources for a wide dissemination in general audience and scientific dissemination for academic communities. The publication of a minimum of two papers in scientific journals and two communications in international symposiums from different fields of research (archaeology-heritage, history of food cultures) are planned as follows:

- International symposium paper presentation targeting the methodological issues of dental calculus investigation: Leiden September 2027 EAA annual meeting https://www.e-a-a.org/EAA/Events/Future_AMs.aspx
- International symposium paper presentation targeting the identification of food culture in the past: Tours IEHCA forthcoming meeting; <https://iehca-internationalconference.eu/fr/accueil>
- A Scientific paper in an IF peer-reviewed journal targeting the consumption of plant in the past: Vegetation History and Archaeobotany; <https://link.springer.com/journal/334>
- A Scientific paper in a diamond open access review (BMSAP; <https://journals.openedition.org/bmsap/>) targeting the dental calculus methodology and the risk/gain for human remains study and preservation.
- An open-access database (as hosted on Nakala or Zenodo platform) with guidelines and photos to identify micro-remains.

Additionally, the LAMPEA has several partnerships with museums (Quinson, Apt, Orgnac), allowing the hosting of a photo exhibition for the public about the "food treasures inside us". Exhibitions are feasible to the MMSH communication services (network of professionals linked to art and culture) and the financial support of ARKAIA and other institutions such as INRAP and the Ministry of Culture. INRAP also has a dedicated office for outreach events and partnerships with cultural places, which allows a touring presentation of the exhibition.

Finally, the LAMPEA laboratory is annually involved in a series of events for school children and the general public, in particular the "Fête de la Science" (October), European Researchers' Night (September) and European Archaeology Days (June). The PhD student and supervisors will have to fit into this programme of events, which is coordinated at the MMSH by the communications department (ex 2024 G. Goude participation to school presentation in Marseille; <https://journées-archeologie.eu/c-2024/fiche-initiative/21564/Musee-d-Histoire-de-Marseille-Ateliers-MMSH>).

Other opportunities may arise for the PhD student and the team to lead activities within Cosquer Mediterranean Cultural Center or cultural associations such as Because U art (<https://www.gpma-asso.fr/des-epaules-et-des-ailes/associations/because-u-art/>). The PhD student will benefit from the supervisors' network in the field of cultural and scientific activities (G. Goude has been an AMU-scientific and technical culture referent for several years).

0000000002 - EXCALIBUR

3. IMPLEMENTATION (2 pages max)

3.1. Work plan

The PhD project EXCALIBUR is scheduled to start on the 1st October 2025 and will last for three years. It will take place in two main laboratories: UMR 7269 LAMPEA, France / University College Dublin, School of Archaeology, Dublin, Ireland. The PhD will be supervised by two main PhD supervisors (Dr G. Goude DR CNRS HDR, UMR LAMPEA, France and Dr R. Power, Researcher UCD, School of Archaeology Dublin). A co-supervising agreement between AMU and UCD will be set up if the EXCALIBUR project is selected for funding.

Additionally, the project EXCALIBUR will be:

- 1) co-tutored in France with Dr L. Bouby (UMR ISEM Montpellier) and in Spain with Dr D.C. Salazar García (University of Valencia, Spain), both scientific collaborators within the ANR programme WomenSOFar;
- 2) embedded in a scientific consortium including INRAP colleagues in charge of the osteological/paraosteological collections in France (Dr Muriel Gandelin in Occitanie, Dr Yves Gleize and Isabelle Souquet in Aquitaine);
- 3) supported by additional palaeoproteomic experts in UCD for the analyses of targeted samples;
- 4) discussed with additional local archaeological fieldworkers to test the setting up of an open access database for microremains identification (Dr Aurore Schmitt UMR ASM Montpellier, Dr Gaëlle Granier UMR ADES Marseille, Bruno Bizot SRA sud-PACA). The researchers mentioned lead different projects and/or collaborating with the proposed supervisors (ANR WomenSOFar, PCR grotte Aeris PACA, PCR Orthez 1814) and/or excavations in France and abroad;
- 5) assisted by local colleagues to provide art-science outreach event (mobile photo exhibition with the collaboration of Dr T. Guiragossian, LAMPEA) supported by the MMSH, INRAP and regional museum partners (Apt, Quinson, Marseille, Aix).

A DMP will be proposed with the PhD candidate in Opidor Platform in November to define the work plan and partnerships with the consortium. The PhD project EXCALIBUR will be divided into four work packages as presented above in figure 1 and below in figure 2:

WP1 Identifying dental calculus microremains. Selection, archiving and non-destructive records of dental calculus from archaeological material. Preparation of samples for optical microscopy and initiation of a machine learning protocol This WP will be carried out in Ireland and in France (acquisition and 2D photo records of new dental calculus samples with INRAP support). Supervision of a master student at the LAMPEA laboratory for skills transfer. As a contingency plan, if do not yield sufficient data on specific food markers like acorn or corn, or if the machine learning model for microremains identification does not perform as expected, the project will still produce a valuable openly accessible dataset of starch variability which will help future researchers.

WP2 Establishing patterns of food culture and sex/age-based diet. Comparison of dental calculus data and stable isotope dietary proxies from human bone and teeth. Exploratory work on food protein identification on targeted samples based on WP1 results (acorn/corn identification).

WP3 Scientific disseminations. Publications on the identification of hidden food resources and new paleo-environmental data. Methodological vademecum for future archaeological studies. Thesis manuscript to be provided in September-October 2028, PhD defence at the end of 2028. All data generated will be made available in open access.

0000000002 - EXCALIBUR

WP 4 Outreach and open access. Creation of a photo exhibition for the general public on the 'treasures of ancient dental calculus' with several partnerships as Musée de Quinson/ Musée d'Apt (LAMPEA agreements). Open access database of micrographs and guidelines for food identifications.

At present, only a very small number of experts are interested in archaeological dental calculus, but this type of study is developing rapidly. Our laboratories (LAMPEA, UCD School of Archaeology) and supporting structures in France (CNRS, AMU, ARKAIA, INRAP) are leaders in European and even worldwide archaeology (ex. <https://lampea.cnrs.fr/spip.php?article4009>). We must therefore continue to propose exploratory projects that can be consolidated into European projects, and promote our dual transfer of skills (in and out).

EXCALIBUR	2025		2026		2027		2028	
	Oct - Dec France	Jan-Oct France Ireland	Oct-Dec Irelande	Jan-Oct Ireland Spain	Oct-Dec France	Jan-Oct France Ireland	Oct-Dec France	
PHD kick-off	Bibliography and sampling prep							
WP1		incl. stay at ISEM	DL1 machine learning protocol			incl. stay at ISEM		
WP2				DL2 communications, incl. stay at Univ Valencia				
WP3		incl. stay with INRAP				DL3 Paper, incl. stay with INRAP	DL4 paper	DL7 manuscript and defense
WP4						DL5 exhibition preparation	DL6 open access db	

Figure 2. Gantt chart of the EXCALIBUR PhD project.

0000000002 - EXCALIBUR

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0000000002 - EXCALIBUR

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