Received: 8 July 2022 | Accepted: 8 March 2023
DOI: 10.1111/arcm.12869

ORIGINAL ARTICLE

The ARchaeological Organic residues Literature Database (AROLD): Construction of a tool for reviewing and querying published lipid data in organic residue analysis

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Funding information
University Nice Côte d'Azur; Centre National de la Recherche Scientifique; Swiss National Science Foundation

Abstract
The first attempts to identify amorphous organic substances in archaeology date to the end of the 19th century and the beginning of the 20th century. The 1960s saw the development of infrared spectrometry, and then separative and mass spectrometry analyses were implemented in the 1980s. But it is only since the 1990s that extended and systematic research programmes were devoted to these substances. The number of publications has not stopped growing and is becoming exponential. To get an overview of the lipid studies in archaeology, we conceived the ARchaeological Organic residues Literature Database (AROLD) as a first structured and collaborative research tool. This paper describes the challenges of setting up such a database, details its architecture, presents the choices involved in its implementation, and discusses the possibilities of sharing and evolving this tool.

KEYWORDS
biomolecular archaeology, collaborative feeding, cross-referencing, database, global scale, lipid, Nakala cumulative deposits, public interface

FROM THE EMERGENCE OF A DISCIPLINE TO A WIDE RANGE OF PUBLICATIONS: BIOMOLECULAR ARCHAEOLOGY OF ORGANIC RESIDUES

Organic residue analysis (ORA) in archaeology and emergence of lipid analysis

From the 19th century onwards, amorphous organic residues were observed on the surface of archaeological artefacts or as free lumps in the archaeological record. First attempts to characterize such materials were carried out through methods available at that time, including density measurement, dissolution in different solvents, combustion, distillation, acid–base reactions or determination of melting point (Cotte & Cotte, 1917; Heintzel, 1980; Lucas, 1914; Moss, 1910). Several hypotheses were then put forward. The presence of materials such as birch bark tar (Heintzel, 1980), milk (Grüss, 1933), and animal or plant cluess (Cotte & Cotte, 1917) were questioned. After these pioneering tests based on experimental chemistry methods, only in the 1960s were modern chemical analysis techniques used to identify archaeological organic materials. Infrared spectrometry, followed by gas chromatography, were investigated for identifying plant resins and tars or the content of Roman amphora (Condamin et al., 1976; Rottländer & Schlichtherle, 1979). In the 1980s, the coupling of Gas Chromatography with Mass Spectrometry (GC-MS) made it possible to unravel complex molecular assemblages through the concept of biomarkers (Evershed, 2008; Evershed et al., 1985; Robinson et al., 1987). These were one-off undertakings resulting from occasional collaborations between teams of chemists or geochemists and archaeologists, for example, for the study of ship caulking (Evershed et al., 1985; Robinson et al., 1987) or Neolithic birch bark tar (Binder et al., 1990).

The 1990s were a turning point in research on archaeological organic residues for several reasons: mass spectrometry made it possible to determine the molecular composition of complex mixtures; robust criteria for the identification of certain materials could be determined on the basis of the concepts of biomarkers, transformation markers and degradation markers; research focused on lipids, which have a higher rate of preservation than other molecular classes in the sediment; and solid reference systems were set up and the processes of transformation and degradation of organic material were investigated.

These advances are the result of the establishment of interdisciplinary research groups that specialize in the biomolecular archaeology of lipids.

Expanding lipid analysis

'Fossil lipids have provided among the best evidence so far of molecular preservation, fully detailed in terms of specific structures' (Eglinton & Logan, 1991, p.318). Indeed, the hydrophobic properties of lipids confer on them a good yield of preservation over time. They are widely distributed in nature and thus provide information on a broad range of natural substances. Finally, they have a great variety of structures, resulting in a high chemotaxonomic potential.

Since the 1990s, it has been shown that lipids absorbed into the porous walls of ceramics can last for millennia, providing evidence of past dietary practices (Evershed et al., 1991): the implementation of an adapted extraction protocol and analysis by High-Temperature Gas Chromatography-Mass Spectrometry (HT GC-MS) (Evershed et al., 1990) led to the identification of plant waxes (Charters et al., 1995), beeswax (Evershed et al., 1997; Heron et al., 1994) and animal fats (Dudd & Evershed, 1998; Evershed & Charters, 1995). The measurement of lipid concentration at different points of the vertical profile of pottery together with experiments on contemporary ceramic vessels showed that lipids preferentially accumulated near the rim in cooking vessels (Charters et al., 1997; Charters, Evershed, Goad, Leyden, et al., 1993). The comparison between the lipid content of the ceramics and the surrounding sediment led to the conclusion that the molecular constituents considered were indeed related to the use of the ceramics and not to migrations from the sedimentary matrix (Heron et al., 1991). Experiments were also carried out to understand the alteration processes of certain molecules (Malainey et al., 1999) and to assess the role of surface treatment (Drieu et al., 2020). The formation of long-chain ketones during heating was demonstrated (Evershed & Charters, 1995; Raven et al., 1997); the influence of bacterial alterations could be studied (Dudd et al., 1998; Regert et al., 1998); the hydrolysis of beeswax esters and the sublimation of alkanes were also demonstrated (Regert, Colinart, et al., 2001).

These fundamental developments have led to a better understanding of the lipid signal trapped within ceramic pottery. Since 1994, δ^{13}C measurements on single compounds were considered together with molecular data (Dudd & Evershed, 1998; Evershed et al., 1994; Stott et al., 1997). Thanks to the setting of reference data, it has become possible to discriminate ruminant and non-ruminant carcass fats and dairy products. In addition, the recognition of degradation markers of unsaturated fatty acids from aquatic resources has opened the way to their identification (Copley et al., 2004; Hansel et al., 2004). To overcome the poor conservation of lipids in some contexts, particularly in the Mediterranean area, the implementation of new extraction protocols has been established. The organic material may be partially polymerized or bound to the ceramic matrix, thus becoming insoluble in organic solvents. It was soon recognized that part of the organic matter could be strongly bound to the inorganic matrix and various extraction methods were developed to access this information (e.g., Correa-Ascencio & Evershed, 2014; Craig et al., 2013; Gregg et al., 2009; Papakosta et al., 2015; Regert et al., 1998; Regert, Dudd, et al., 2001). These methodological developments have resulted in the identification of new biomarkers, increased extraction yields and/or optimized preparation times.

Research based on soft ionization methods with high-resolution mass spectrometry is interested in accurately determining triacylglycerol distribution when they are preserved for a more precise identification of animal fats (Mirabaud et al., 2007) or plant oils (Garnier et al., 2009; Oras et al., 2017; Saliu et al., 2014).

Nowadays, specialists have an arsenal of sample preparation protocols and analytical techniques to address a wide range of natural lipid substances related to ceramic vessels, hafting adhesives, faeces, bog bodies and sediment content:

- Terrestrial animal fats, ruminant and non-ruminant carcass fats (Mukherjee et al., 2007; Regert, 2011).
- Dairy products (Craig, Chapman, et al., 2005; Craig, Taylor, et al., 2005; Debono Spiteri et al., 2016; Evershed et al., 2008).
- Bog bodies (Evershed, 1990; Evershed & Connolly, 1988).
- Beeswax (e.g., Heron et al., 1994; Needham & Evans, 1987; Regert, Colinart et al., 2001; Roffet-Salque et al., 2015).
- Shellfish, and fish, marine and freshwater fats (e.g., Craig et al., 2011; Hansel et al., 2004; Lucquin et al., 2016).
- Legumes, cereals, leaves and specific plant oils (e.g., Copley et al., 2001, 2005; Hammann & Cramp, 2018).
- Birch bark tar (e.g., Charters, Evershed, Goad, Heron, & Blinkhorn, 1993; Rageot et al., 2021; Regert et al., 2003, 2019).
- Pine resin and tar (e.g., Evershed et al., 1985).

Lipids analysis as a new proxy in archaeology

Since the 2000s and even more since 2010, lipids have become essential ecofacts in archaeology. Natural resource management, herding practices, pottery function, food systems, trade in specific commodities and adhesive crafts are some of the themes that can be addressed from this proxy. Lipids are also a dating medium (e.g., Berstan et al., 2008; Casanova et al., 2020; Stott et al., 1997) and

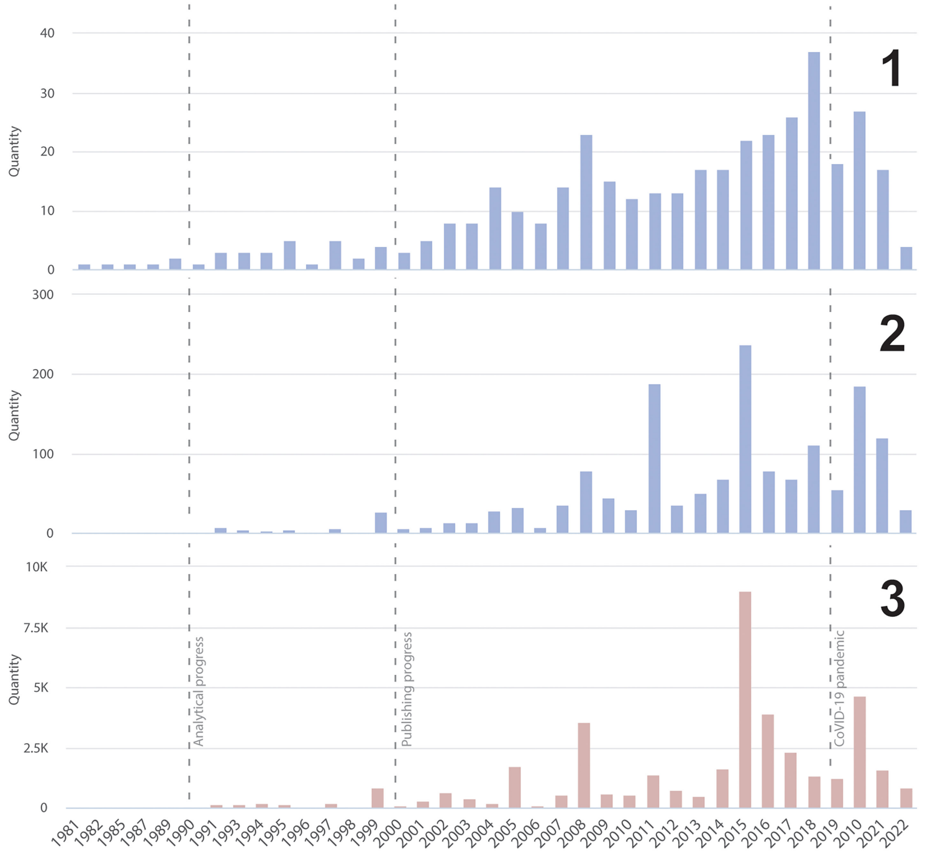

FIGURE 1 Number of papers in Organic Residue Analysis (ORA) in archaeology per year (data extracted from the AROLDatabase, including doctoral works): (1) papers per year; (2) archaeological sites handled per year; and (3) samples reported in the literature per year.

provide environmental information (Roffet-Salque et al., 2018). Increased scientific activity has yielded discoveries such as the oldest traces of the exploitation of certain commodities, including plants, cow or horse milk, beeswax or cheese (Dunne et al., 2016; Evershed et al., 2008; Outram et al., 2009; Roffet-Salque et al., 2015; Salque et al., 2013).

The geographical areas investigated are multiplying from Europe, where the pioneering work was done, to Asia (Craig et al., 2013; Shoda et al., 2017), Africa (Copley et al., 2004; Dunne et al., 2016, 2019) and, to a lesser extent, the American continent (Taché et al., 2017). India, the Arabian Peninsula and the Caucasus are also regions that are now explored (Manoukian et al., 2022; Suryanarayan et al., 2021, 2022).

The latest studies since 2015 are highly interdisciplinary and collaborative in order to combine different approaches to the same issues (e.g., Debono Spiteri et al., 2016; Dunne et al., 2016; Hendy et al., 2018), re-emphasize experimental approaches to refine interpretations (Admiraal et al., 2020; Bondetti et al., 2021; Miller et al., 2020; Reber et al., 2019) and include ethno-archaeological investigations that are helpful to better understand archaeological data (Drieu et al., 2022; Dunne et al., 2019).

The literature testifies to this rise with an increasing number of publications concomitant with the study of large series of several hundred, even thousands of samples (Figure 1).

The success of lipid approaches is demonstrated by the explosion of published data, the constant increase in the corpus studied, the multiplication of the chrono-cultural contexts considered and the diversification of the questions addressed.

Recent synthesis articles provide an overview of the breadth of research highlighting some of the commodities (Cubas et al., 2020; Debono Spiteri et al., 2016; Evershed et al., 2022; Lucquin et al., 2016; Rageot et al., 2021; Roffet-Salque et al., 2015), but still, they require prompt updating.

Furthermore, the preparation and analysis protocols differ according to the research teams, several papers deal with multiple sets of samples from the same site, and contextual information is sometimes partially provided, especially in synthetic review articles.

To overcome the current difficulty of dealing with this large and growing literature, we have set up the AROLDatabase.

Why a bibliographic database on organic residues in archaeology? The challenges of the AROLDatabase

The project fulfils a triple objective. First, to survey the literature on the characterization of archaeological lipids and record published data in a standardized format. Second, to provide the scientific community with a data inventory and query tool. Third, to assist in the production of synthesis documents including distribution maps of the materials investigated, the chronology of published data, the type of artefacts studied (e.g., arrowheads, bell-shaped vases, cooking pot, etc.), protocols of sample treatment or analytical techniques implemented.

Holding these thoughts, we have compiled, synthesized and built a comparative bibliography template that can be used as a tool for single and/or multiple search criteria (e.g., region, chronology, products, type of samples, preservation context): the ARchaeological Organic residues Literature Database (AROLDatabase). At present, while the findings from a single site used to be scattered in several articles, the AROLDatabase brings together the published archaeological organic residue data from a single site, also by distinguishing between sample lots and chronological layers, providing a synthetic view of the available data.[1]

CONCEPT AND ARCHITECTURE OF THE DATABASE

From published data to a standardized database

Synthesizing data on lipid analysis in archaeological artefacts has proved to be a challenge for two main reasons. First, while some articles were published on a one-site, one-period basis, many articles compile data on several archaeological sites and/or several periods or cultural contexts. In addition, some of the papers compile previously published data with new data. Data relating to the same site and chronological period, or cultural phase, are sometimes scattered throughout several papers. Bearing this in mind, we have chosen to use each paper as a cornerstone to design the architecture of AROLD. From one ‘publication’ to another, the number of samples analysed can vary from one to several hundreds. As it is not always possible to fill in the database on a sample-by-sample basis, we chose the ‘sample lot’ model. A ‘sample lot’ consists of samples from the same site and period or cultural context, but depending on the completeness of the data, the samples can come from one or several archaeological layers. Hence, a ‘publication’ may present data from the analysis of several lots, when a diachronic study of the site has been carried out. Similarly, several publications may refer to the same sample lot, when various issues have been addressed and presented in the different articles. To account for cases where several teams worked on the same site and the same period, two sample lots are created. A ‘site’ tab has been created for each archaeological site. Every ‘sample lot’ is linked to an archaeological ‘site’, and a ‘site’ can be linked to several ‘sample lots’.

The second challenge is the heterogeneity of metadata related to each ‘sample lot’ and the diversity the analytical procedures carried out. By structuring AROLD, we defined and ranked the essential criteria to be recorded which were converted into fields to be input as numbers, texts or lists: contextual archaeological data (site, period, culture, conservation context, etc.), types of objects studied, analytical procedures carried out and identified substances. To facilitate the comparison of text fields from one article to another, we produced pre-edited drop-down lists representative of the data available in each article. Semantic choices for the main parameters are detailed in Data S1 in the additional supporting information.

Current and ongoing content of the AROLDatabase

The database is primarily fed from peer-reviewed articles and academic output, including supplementary materials and related papers, to get more detailed information on the archaeological sites under consideration (especially concerning dating, location, environment or culture). Among the ORA literature, we chose to focus on lipids. To gain an overview of food commodities and beverages, we also included data on fermented beverages, particularly short-chain acids involved in wine and beer and alkaloids present in cocoa on the American continent. At this stage of the database input, we have not included proteins, sugars and anything related to colouring matters. However, the database is designed to be expanded to include these types of substances at a later stage. Articles relating to ancient DNA are not referenced either.

Another issue to be addressed was the quality of the data published, the robustness of the results obtained and the validity of the interpretations. Even though the database is mainly based on peer-reviewed articles, the expansion of ORA research is occasionally accompanied by a lack of expertise in the methods used or the interpretation of the data as recently discussed by Whelton et al. (2021), although guidelines are now accessible (Dunne et al., 2017; Roberts et al., 2018). As the aim of this database is to compile and share published scientific data, we have chosen to start by using all published data in the first instance, arguing that it is crucial for any user of the database to critically read the articles they intend to cite afterwards. In a forthcoming step, the database could be updated with fields opened for scientific debate between the contributors to the database and the authors of the articles.

In this initial implementation phase, only a few scholars contributed to the database, via an interface hosted by Filemaker Server (Figure 2).

This interface dedicated to contributors is accessible through a standard web browser protected by individualized access codes in such a way that a personalized monitoring of modifications can be carried out (Figure 2). This workspace is composed of five tabs: 'Home' presents the database, the user information and the latest modifications recorded; 'Literature', 'Site ID' and 'Sample lots', are the pillars of the database; and 'Data display' allows the visualization and representation of data by means of graphs, time scales and distribution maps.

These features are based on the open-source JavaScript libraries leaflet (v1.7.1[2]) for mobile-friendly interactive maps and high charts to create responsive and interactive charts. The AROLDatabase makes possible the import of bibliographic references from Zotero or Mendeley. Each contributor to the database can thus enter the access key to at least one personal library on Zotero[3] and one on Mendeley[4] in the 'Home' tab. The current dataset used in this database is available in a French national data repository (Nakala) and will be regularly updated with new data.[5]

As some publications do not provide enough detail to be properly comparable with publications supplying supplementary information, we wish to make AROLD a participatory and common tool, where scholars can consult data from their own work and contribute information that has not been detailed in the published papers. In future, the structure of the database in PostGreSQL format will therefore be available in the Nakala repository in order to facilitate the reuse and appropriation of the database by others. For developers, a REST API will be available upon request and acceptance by the project leaders.

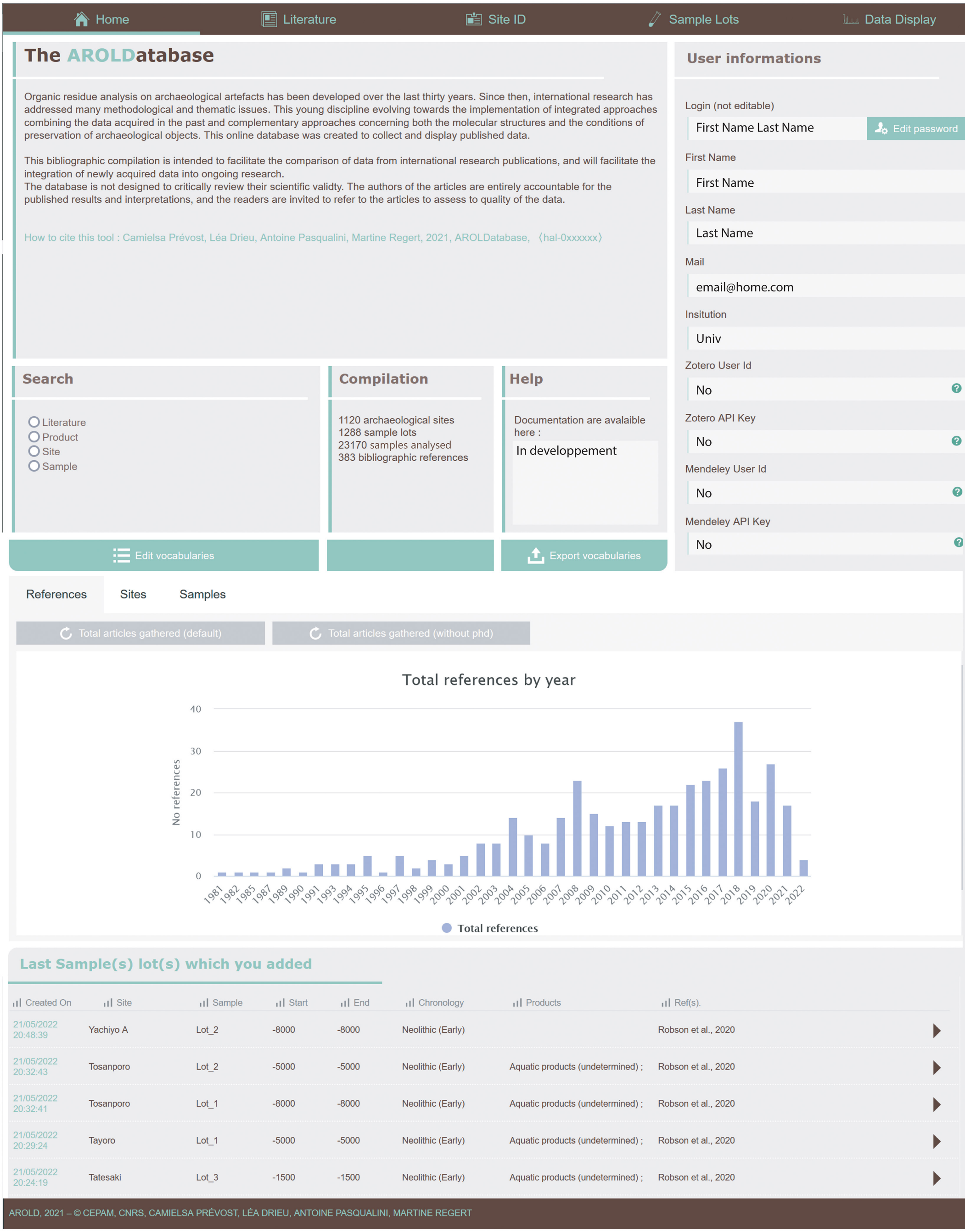

FIGURE 2 'Home' interface dedicated to contributors (user information is masked on the example).

QUERYING THE DATABASE

Data consultation

Two ways of browsing the database have been set up:

- One open-access version including published and academic data is available.[6] Querying the dataset is performed through a search engine and drop-down lists. This webpage also generates a json+ld tag whose json structure is established according to the dataset model, established by schema.org[7] (Figure 3). All documents created using the public interface must be copyrighted as detailed on the web page and according to the data set.[8]
- Another working interface is available (with a personal password restricted access) for colleagues who wish to consult, input, complete their data or further develop the database (Figure 2).

Public sharing is made possible because it involves reviewing data already published elsewhere and referring to the original publication. At this stage of setting up the database, contributions of data are not subject to scientifically moderated, but this may be implemented at a later stage. A ticket support is available to report errors or comments to the database developers.

Case study in the AROLDatabase

To highlight the opportunities opened by this new tool, a query for aquatic products identified in Neolithic ceramics was chosen as case study, as detailed below.

At the time of writing, the database contains 1214 archaeological sites and 1570 sample lots (Figures 4–6). Among them, 59 literature references and 118 sample lots are related to Neolithic aquatic products. From this query a distribution map and list of sites with relative chronological information are produced by the database (Figure 4) (see Data S2 in the additional supporting information). Selected maps detail the results according to the type of aquatic substances (marine, marine mammals, freshwater and undetermined aquatic products; Figure 4, 2) and products encountered into the same corpus (other animal fats, Figure 4, 3; dairy products, Figure 4, 4; beeswax or birch bark tar, Figure 4, 5). Commodities were not necessarily mixed in the same containers but were collected in the same archaeological environment. For Neolithic seafood research, mapping data highlights an intensive focus on two regions, namely Japan and the Korean peninsula (Craig et al., 2013; Shoda et al., 2017) and Northern Europe (Heron et al., 2015).

These charts maps can be used to initiate archaeological discussions, such as the three following topics. First, archaeological issues, such as those concerning preservation contexts or type of site. Here, some of the findings described as marine resources originate from field far from the coast, which raises the question of how the land was used and how the products were moved. Such matter could be further explored by checking the interpretations produced in the article, the accuracy of dating or periodization, and coastal location during the Neolithic.

Second, chronological issues, such as how seafood exploitation has evolved over time, can also be tested drawing up maps by choosing the time step appropriate to the research objectives. The maps in the following figures show the data available for all periods and continents, and from the Mesolithic to the Middle Ages (Figure 5).

Third, methodological issues, as with screening of data by extraction and analytical methods, it becomes possible to assess how the data were obtained. One must note that many studies confirming the presence of aquatic fats are based on isotopic results on single compounds (95%), most often using an acid methanol extraction. It can also be noticed that these substances have only been characterized for the last 20 years (Figure 6), in connection with the combination of molecular approach by GC and GC-MS with Isotope Ratio Mass Spectrometer (GC-c-IRMS).

PERSPECTIVES: RECOMMENDED DATA AND METADATA

- Retrieving data to fill the database generally involved the tedious unravelling of articles, including the supplementary information. Standardizing the data for comparison with the existing literature occasionally requires interpreting the limited information provided. Some publications do not

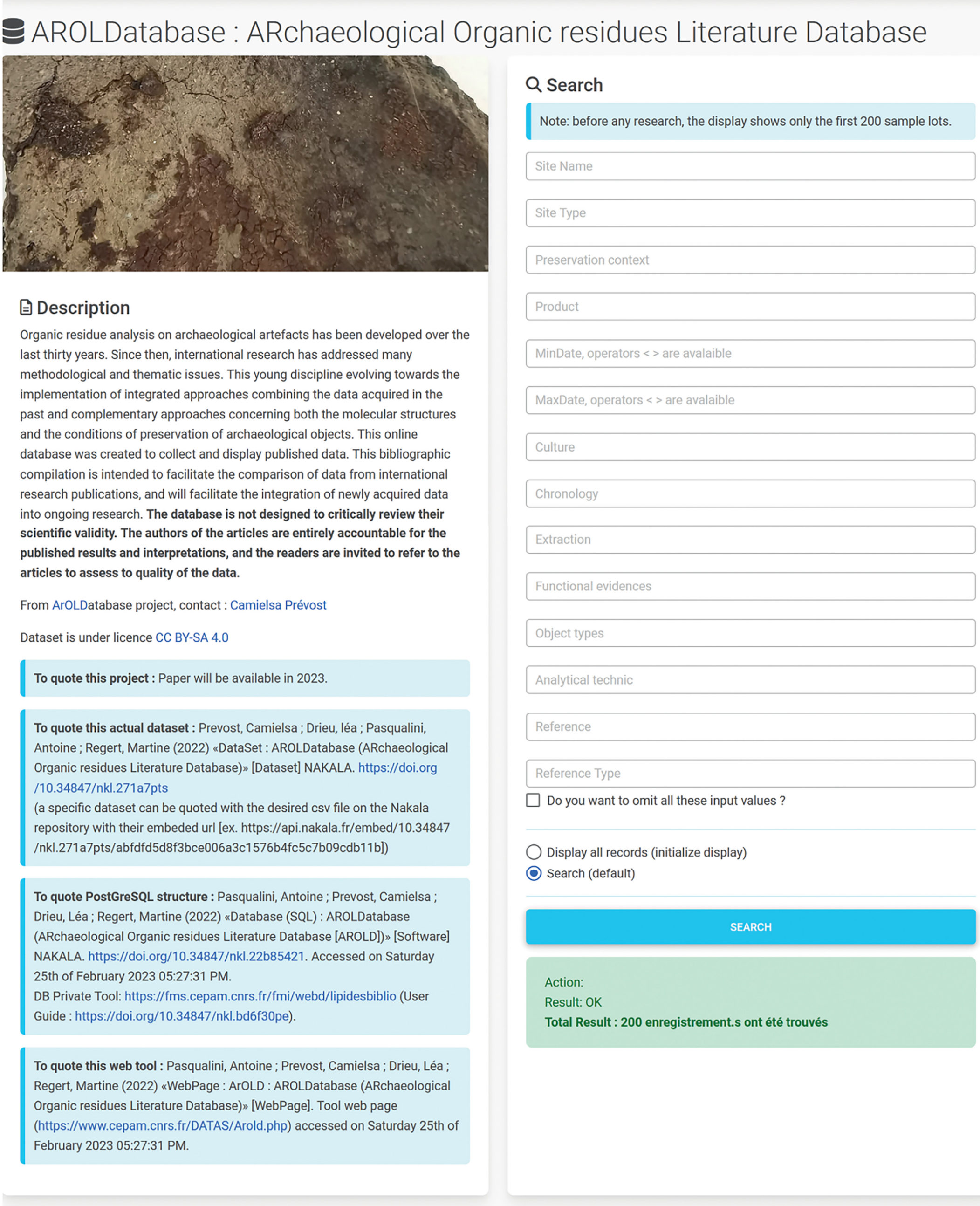

FIGURE 3 Overview of the open access web page of the AROLDatabase.

provide enough details to be properly compared with the most detailed papers: most of the time, the coordinates of the investigated sites are missing (sometimes no map is even provided), and the geological contexts and the post-excavation course of the objects are poorly commented (in particular for museum collections).

- Papers do not always specify the extraction method (e.g., conventional solvent extraction or acid methanolysis) leading to the extraction yields mentioned in the text or tables, which makes the

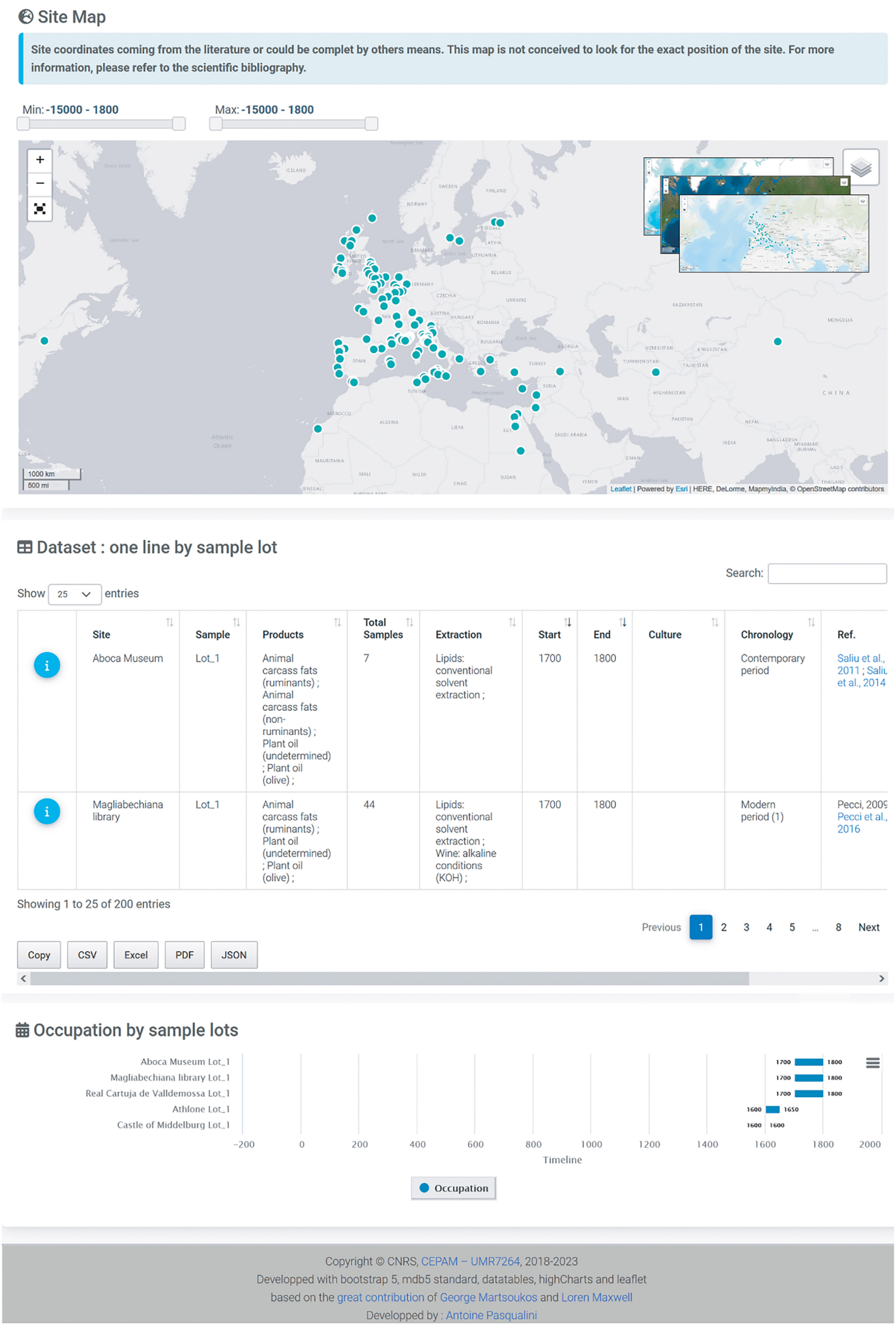

FIGURE 3 (Continued)

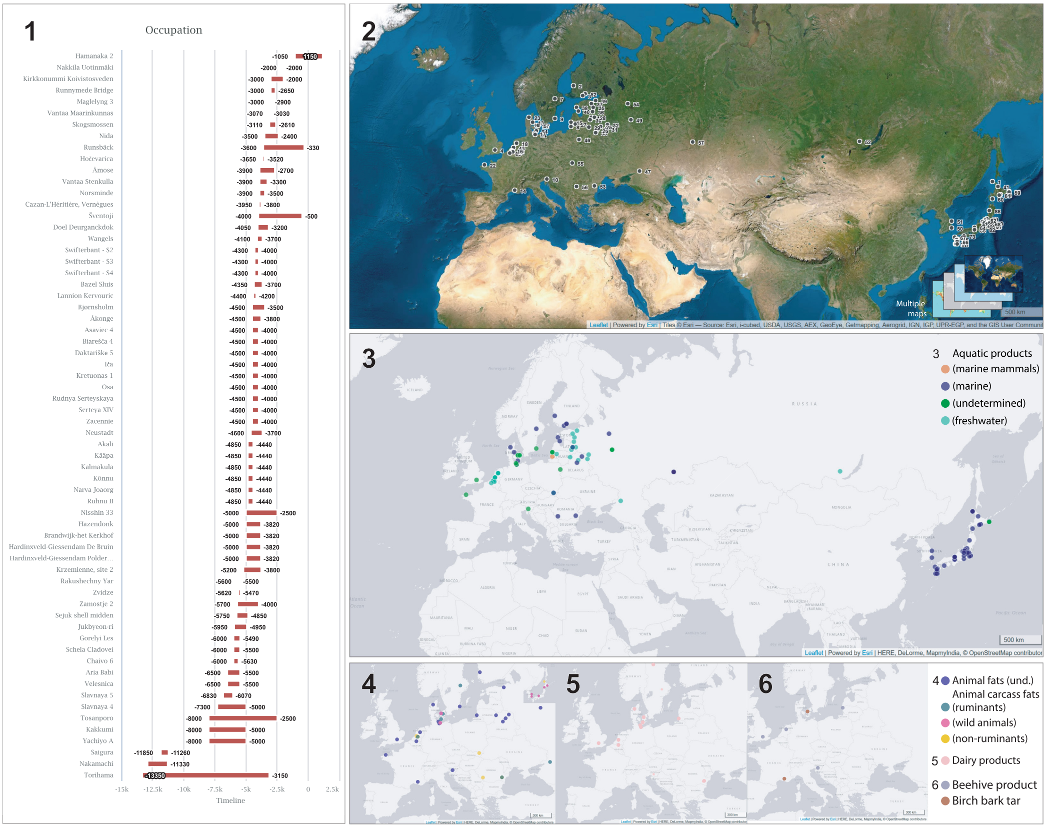

FIGURE 4 Series of documents from the AROLDatabase on aquatic products: (1) bar chart indicating the date for each archaeological site reported in AROLD where aquatic commodities have been identified; (2) satellite map with the location of sites containing information on aquatic molecules from Neolithic sites reported into AROLD; (3) map with detailed indications of the type of aquatic products discussed in the papers; and (4–6) maps showing other products identified at sites where aquatic products have also been identified. The caption of the map (2) together with the corresponding references are provided in Data S2 in the additional supporting information.

comparison with the published literature meaningless, as different methods may have significantly differing extraction efficiency.

- Some articles mention maximum, minimum, mean and/or median extraction yields, without specifying whether these data refer to all samples or only those considered interpretable.
- While the commodities identified in each sample are available in a table in some articles, this information is often only partially reported and/or left to the interpretation of the reader, for example, in the form of a graph representing the values of stable carbon isotopes in palmitic and stearic acids.
- The study of the exploitation of natural resources over time is hampered by the absence of calibrated dates and/or chronological period in some papers. Depending on whether the query is made by chronological period or over a range of dates, the results obtained will be different, which is a limit to the use the database for a diachronic study (e.g., to investigate the origins of the exploitation of a specific commodity in pottery).

This scanning and analysis of the publications led us to identify and formalize the data and metadata necessary for an optimal comparison of the results published and for a good knowledge of the contexts of discovery (type of site, stratigraphic and chronological control, context of preservation, etc.).

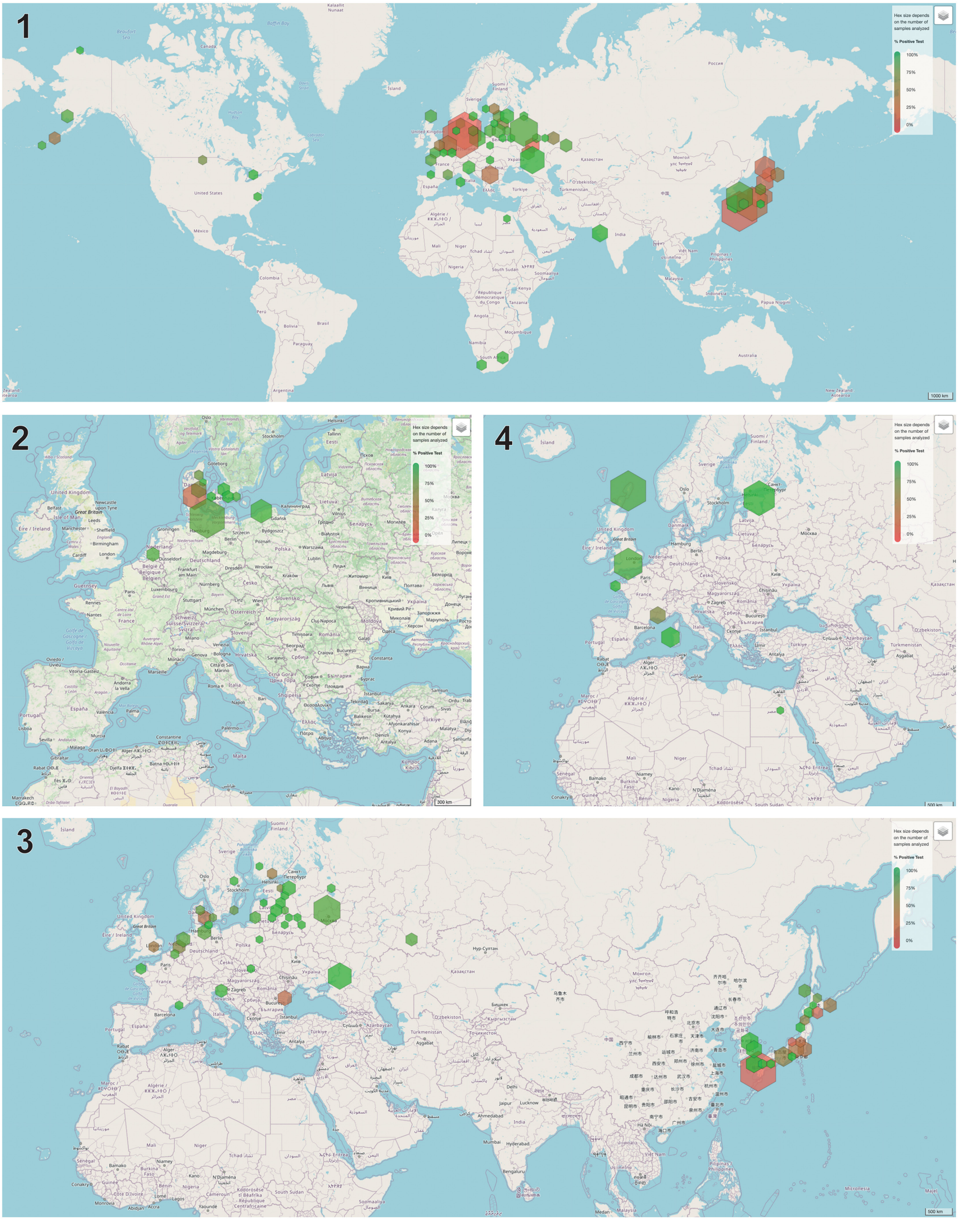

FIGURE 5 Examples of HexBin world maps from the AROLDatabase with information on aquatic molecules. These different maps correspond to: (1) all periods, (2) Mesolithic, (3) Neolithic and (4) antiquity and the Middle Ages. There are based on the lipid extraction yield from ceramic vessels regardless of the type of extraction carried out or the samples investigated (sherds or carbonized residues).

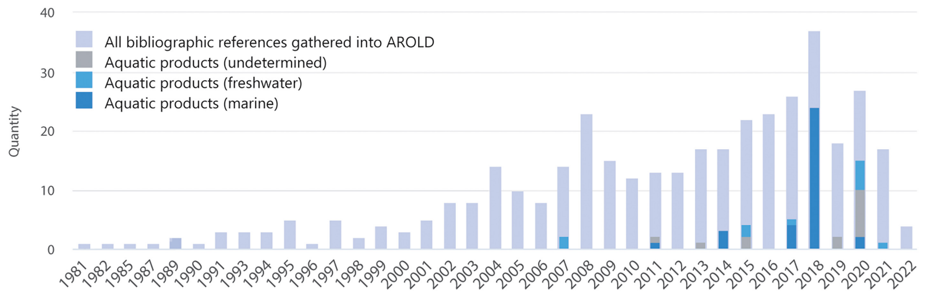

FIGURE 6 Highlight of the number of papers concerning the aquatic commodities published per year gathered into AROLD. The bar chart shows the recent interest in the research papers for these kinds of substances, including freshwater and marine animal fats (blue, light blue, and grey bar sections).

We provide below a list of recommended data and metadata that should be included with each publication concerning the context of discovery, the materials investigated, the analytical protocols and the results obtained in terms of commodities identified:

- The location of the discovery should be indicated in an international geolocation system—preferably DD (decimal degrees) or DMS (degrees, minutes, seconds). Otherwise, to protect the sites from clandestine excavation, the nearest locality could be indicated.
- Preservation context, environmental climatic context of the discovery and year(s) of the excavation should be mentioned: 'arid/semiarid', 'burnt site', 'continental (humid)', 'equatorial', 'Mediterranean', 'waterlogged', etc.
- Minimal site specification should be described: 'cave', 'cementery', 'coastal', 'dolmen', 'domestic site', 'rock shelter', etc.
- Specific cultures and global periodizations comparable at regional and international scales should be specified. Metric dates should be expressed according to the most widely used international systems, either in BP or in BCE/CE, citing the calibration curve used and the dating medium. It must be clear in the paper that the date is related to the archaeological level that contains the artefact or the artefact itself.
- A concise description of the items studied (objects or groups of samples) should be written, linked to cross-references: the type of object(s) ('cooking stone', 'hinge part', 'human bone', 'ornament', 'sherd', 'vessel (whole)', 'work of art', etc.), the constituent material(s) (bone, ceramic, glass, metal, stone, vegetable, etc.) and functional information (amphora, arrowhead, beaker, beehive, lamp, storage, transport, etc.) when available are interested data to document. Reporting the proportion of analysed objects in the total associated assemblage indicates how representative are the obtained data.
- Sampling modalities, the sample mass (or size) material, pretreatment protocols, storage conditions, analyses carried out and analytical conditions implemented are necessary to describe (at least in the supplementary data).
- The yield of extraction should be provided for each sample, including for those characterized by the absence or low yield of lipids, together with the type of extraction. When such information is present, then anyone can do all the calculations necessary to compare data between several papers (mean, median, etc.). In a same table, the list of the molecules identified can be presented with the conclusion on the type of product(s) determined.

More complete datasets would enable AROLD to address additional issues (see Table S1 in the additional supporting information) and develop new charting representation options.

CONCLUSIONS: DATA SHARING AND ACCESSIBILITY

The AROLDatabase provides an overview of the published literature in lipid archaeology concerning a period, a region, a commodity or combination of these criteria, through several options for interacting and searching:

- Use the open access for scholarly query.[9]
- Participate as contributors by adding and modifying data via a restricted access work interface.
- Be involved as future database structure developers.

Presently, AROLD, can be used as a bibliographic synthesis template to review the state of the art when starting a project or an article.

Despite the great heterogeneity of the data provided in the literature, the analytical information could be standardized and data on the archaeological context could be systematically collected and documented when available in the articles (location of the site, type of site, chronology, context of preservation). Building this database opened new perspectives for a better integration of fundamental data and metadata in the papers. This burgeoning tool is now available for the research community and ready to be further collegially enhanced and to receive new inputs.

ACKNOWLEDGEMENTS

We thank the pioneers who studied lipids in archaeology and all their collaborators and successors who built this research framework in which preliminary synthesis and large-scale reflection are now possible through all this publication work. We are grateful to the University Nice Côte d'Azur, the CNRS (Centre National de la Recherche Scientifique) and the SNF (Swiss National Science Foundation—with the SINERGIA project 'Foodways in Africa') for their support. Indeed, in the framework of this latter project, it was possible to feed the database particularly with published studies on Africa. We also sincerely thank the reviewers for their thorough proofreading of the article and exploration of the database and for their sound advice.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are openly available in nakala.fr.

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ENDNOTES

1 Copyright terms for datasets and SQL structure are defined by Creative Commons at https://creativecommons.org/licenses/by-sa/4.0/deed.en (CC-By-SA 4.0; C. Prévost, L. Drieu, A. Pasqualini and M. Regert).

2 Cf. https://leafletjs.com/.

3 For web api v3 documentation, see https://www.zotero.org/support/dev/web_api/v3/start/.

4 For api documentation, see https://dev.mendeley.com/.

5 For DublinCore metadata of this database (including this public and private access url), see https://nakala.fr/10.34847/nkl.271a7pts/.

6 See https://www.cepam.cnrs.fr/datas/arold.php/.

7 See https://schema.org/Dataset/.

8 For the AROLDatabase, see https://doi.org/10.34847/nkl.271a7pts/.

9 See https://www.cepam.cnrs.fr/datas/arold.php/.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Prévost, C., Drieu, L., Pasqualini, A., & Regert, M. (2023). The ARchaeological Organic residues Literature Database (AROLD): Construction of a tool for reviewing and querying published lipid data in organic residue analysis. *Archaeometry*, 1–19. https://doi.org/10.1111/arcm.12869