ARCH-ON: a new ontological framework to describe archaeological objects for Digital Humanities research

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Pieterjan Deckers[1,*], Eero Hyvönen[2,3], Michael Lewis[4,3,5], Eljas Oksanen[5,3], Heikki Rantala[2] and Jouni Tuominen[3,2]

[1]KU Leuven, Belgium
[2]Aalto University, Finland
[3]University of Helsinki, Finland
[4]British Museum, UK
[5]University of Reading, UK

Abstract

This paper presents the idea and preliminary results of the ARCH-ON (Archaeological Ontologies) pilot project. This project aims to lay the groundwork for the semantic description and classification of archaeological artefacts, enabling new approaches to the recording, study, international data harmonization and public accessibility of information regarding material culture from the past.

Keywords

archaeology and history of religion, data harmonization, Europe, Linked Open Data, Middle Ages, ontologies

1. Introduction

Since the 19th century, archaeological artefacts have typically been organized into typologies or classified by their physical features, particularly their form (Read 2016). Although this kind of Knowledge Organization Systems (KOS[1]) (e.g., Zeng and Mayr 2019; Hjørland 2008) in use today are a powerful framework for assessing, categorizing and investigating archaeological materials, the approach comes with inherent flaws and artificial limitations, not least in the context of digital datasets (cf. Deckers 2021; Lewis, Ehrnsten, et al. 2025; Lewis, Oksanen, et al. 2025):

1. The framework is **not neutral**. Typologies rely on the hierarchical organization of a selection of traits found within a delineated group of artefacts. Deliberate choices are made in this process to best serve the purpose of the classification (e.g., answer a specific research question). Consequently, any classification reflects only one of numerous possible ways to organize the material.
2. The framework is **inflexible**. As new finds are made, as specific assemblages from a site or region are studied, or as the scope of an archaeological category is redefined, existing classification schemes may no longer suffice.
3. The framework is **rooted in** and reinforces outdated and sometimes **problematic conceptions of culture**. Typically, each artefact is given its place in a branching hierarchy of classes and subclasses, with impact both on scientific analysis (e.g., for artefact chronology) and for academic and public preconceptions, such as regarding the cultural associations of specific artefact classes.

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*Corresponding author.
pieterjan.deckers@kuleuven.be (P. Deckers); eero.hyvonen@aalto.fi (E. Hyvönen); mlewis@britishmuseum.org (M. Lewis); e.i.oksanen@reading.ac.uk (E. Oksanen); heikki.rantala@aalto.fi (H. Rantala); jouni.tuominen@helsinki.fi (J. Tuominen)
https://seco.cs.aalto.fi/u/eahyvone/ (E. Hyvönen); https://seco.cs.aalto.fi/u/jwtuomin/ (J. Tuominen)
0000-0002-7033-516X (P. Deckers); 0000-0003-1695-5840 (E. Hyvönen); 0000-0001-5933-8557 (M. Lewis); 0000-0002-7468-9256 (E. Oksanen); 0000-0002-4716-6564 (H. Rantala); 0000-0003-4789-5676 (J. Tuominen)

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[1]Encyclopedia of Knowledge Organization: https://www.isko.org/cyclo/kos

4. From a technical perspective, parallel classification schemes produced by scholars operating within the framework of modern nation-states are **suboptimal for transnational data harmonization** (Sawicki, Lewis, and Vargha 2024). Different classification schemes, for instance those used within or among different countries, are largely not semantically interoperable. This includes archaeological inventories and other datasets maintained by many national heritage agencies, but also with finds recording schemes that have been established in several north- and west-European countries to make public finds available (i.e., those found by the public, including metal-detecting hobbyists) for research and consultation (Lewis, Ehrnsten, et al. 2025; Wessman et al. 2023).

In the pre-digital world, the biased and inflexible nature of typology was mitigated by producing new classifications, guided by updated theoretical conceptions and/or expanded finds corpora. The research history of many archaeological artefact categories is characterized by a series of publications refining existing typological schemes and creating new ones. However, the digital revolution in the humanities, and cultural heritage in particular, has brought about a new set of uses for artefact classification that highlight and exacerbate the inherent problems of traditional approaches.

Digital classifications are just as one-sided as their precursors. However, through their continued use they can achieve a dominant status in the description and study of artefacts and preclude the formulation of alternative approaches (the 'winner takes all' phenomenon, Hindman 2009). To address these fundamental issues of representing archaeological knowledge in a transnational setting, a relational, attribute-based approach has been proposed in the past by one of the authors (Deckers 2021). Though these approaches are not new (e.g., Clarke 1968; Plutniak 2022), a digital implementation of this approach, driven by advancements in semantic Linked Open Data (LOD) technologies in cultural heritage (e.g., Hyvönen 2012), holds significant potential in advancing the study and presentation of artefact data, including facilitating the aggregation of datasets into larger data services and portals for DH research, such as the Pan-European AriadnePlus[2] and national ones like FindSampo (Rantala et al. 2021; Hyvönen et al. 2021).

The ARCH-ON pilot project[3] focused on a new attribute characterization and LOD-based approach to artefact description and classification, taking specific classes of archaeological metalwork as a case study. As noted, thanks to the substantial efforts to record and publish detector finds through several large initiatives in north-western Europe, this finds category now sits at the forefront of the digitization of artefact collections (Lewis, Ehrnsten, et al. 2025). Consequently, metalwork artefacts serve as the focus for the conceptual development of this new approach.

2. Towards semantic artefact description

To meet the challenges set out above, ARCH-ON will describe artefacts and artefact classes in semantic terms by modeling their relevant traits. While multiple projects have sought to model other aspects of archaeological research, notably fieldwork,[4] but also a common international ontology and data model for numismatic records by Nomisma[5] (Gruber and Meadows 2021), the archaeological description of artefacts in general has hitherto not been treated as a subject for semantic modeling. Similar limitations exist in the field of vocabularies: while several thesauri exist that include high-level concepts for artefacts, such as Getty AAT[6] and FISH[7], these rarely contain the depth, detail and flexibility required to meet the needs of archaeological researchers and other stakeholders.

The underlying philosophy of our approach is one of pragmatism. Rather than representing an ideal knowledge graph of artefact traits and contextual attributes, the aim is to create a common language for

[2]AriadnePlus infrastructure: https://ariadne-infrastructure.eu/
[3]ARCH-ON project homepage: https://seco.cs.aalto.fi/projects/arch-on/
[4]See, e,g., https://cidoc-crm.org/crmarchaeo/ and http://openarchaeo.huma-num.fr
[5]Nomisma initiative: https://nomisma.org
[6]Art and Architecture Thesaurus: https://www.getty.edu/research/tools/vocabularies/aat/
[7]FISH terminologies: https://heritage-standards.org.uk/fish-vocabularies/

the semantic description using existing concepts and categorizations. This will accommodate disparate approaches to artefact description and facilitate the integration of existing datasets.

A second design principle is similarly pragmatic: to make use, to a maximal extent, of existing models and ontologies. Wherever possible, we encourage the re-use of established vocabularies (such as the already-mentioned AAT and FISH) in the semantic description of attributes, and of existing properties and classes (e.g., from CIDOC CRM[8]).

In the following section, we illustrate our approach through a semantic description of a particular object. It should be seen as a preliminary example that explores some of the practicalities, challenges, and potential of this approach.

Figure 1: A late medieval ampulla (PAS record ID SWYOR-19485D) with the presumably apotropaic symbol "looped square" on one side and a bird on the other, recovered by metal detecting in North Yorkshire, England. The object has been pierced on one side, possibly to let out the holy water it had contained. Image credit: The British Museum and the Portable Antiquities Scheme.

3. Case example: a medieval pilgrim's ampulla from North Yorkshire, England

We have selected medieval pilgrims' ampullae as a case-study example to develop the ARCH-ON data model. These small tin or lead (or alloy thereof) flasks were used to hold and transport holy liquids, including water and oils, from sacred places. As such, they contained tangible materials that, when used in potions or balms, were believed to have miraculous qualities that could cure and protect (Boertjes 2019, 57-58). In addition to their contents, the vessels themselves were valued as touch relics that held or had been in contact with holy matter (Højmark-Søvsø 2024).

The tradition of collecting holy liquids was not new, but the use of lead-alloy vessels grew towards the end of the 12th century (Spencer 1998, 38-39). During the Later Middle Ages (1350-1550), ampullae were produced in significant numbers. The relative ease with which ampullae could be made – once a mould had been created or acquired – meant that they could be produced at various locations and sold at prices many could afford. Ampullae are, therefore, a relatively numerous example of medieval

[8]CIDOC Conceptual Reference Model (CRM): https://cidoc-crm.org

portable objects that (as will be shown) potentially encode significant information about religious life and ritual activity.

An intriguing facet of ampullae, relevant to the ARCH-ON project, is not only that their forms differ – although later ampullae are more standardized than the earlier types (Spencer 1990, 58) – but they also have various designs upon them (Anderson 2010). As will be outlined below, attempts have been made to classify these features and attributes with varying success, also enabling ampullae to be hypothetically linked with various cults or shrine sites.

Our example ampulla[9] (see Figure 1) was recovered near Ripon in North Yorkshire, northern England. It was manufactured by casting, and the main design features are a doubled "looped square" symbol on one side and a bird on the other. The looped square, also known as "Saint John's Cross" in English and familiar to modern audiences from the Command key on Apple computer keyboards, is an ancient pre-Christian symbol encountered in the Nordic countries. Presumably apotropaic, its oldest attestation in Finland dates to the 11th century[10] (Talve 1990). This is the only known use of this symbol on an ampulla found in England (and to the authors' knowledge anywhere). The object has been pierced, possibly to gain access to the holy water once inside. Several such pierced or cut-open ampullae are known, and it has been suggested the water transported from the pilgrimage site was deployed for religious and ritual purposes back at home (Anderson 2010: 197–200).

3.1. Towards the ARCH-ON data model

The ARCH-ON data model draft is illustrated here as graph diagrams based on three aspects of the example ampulla: intrinsic characteristics (see Figure 2), extrinsic characteristics (see Figure 3), and design elements and interpretative characteristics (see Figure 4). The diagrams are visual representations of the core attributes of the ARCH-ON data model as a knowledge graph, with direct mapping to concrete RDF serialization. The green rectangle represents the object itself, rectangles with orange background are data instances for modeling complex attributes, rectangles with blue background are concepts in controlled vocabularies, and rectangles with white background represent literal values. The arrows between rectangles represent properties. The prefix *crm:* refers to the CIDOC CRM ontology, *dct:* to the Dublin Core metadata terms[11], *foaf:* to the FOAF vocabulary[12], and the empty prefix *:* to the ARCH-ON data model schema (including controlled vocabularies created for the case study, for simplicity).

Figure 2 illustrates how intrinsic characteristics are represented in the ARCH-ON data model. The physical dimensions of an object are modeled so that their type (e.g., weight), value (e.g., "58.32"), and unit (e.g., gram) are represented using distinct properties. The type and unit of a dimension are defined using controlled vocabularies of types and units, respectively. Similarly, the material, object type, general shape, primary production technique, completeness of the overall shape and modifications are represented using controlled vocabularies. In Figure 3, extrinsic characteristics of the example ampulla are illustrated: dating, find location, discovery method, and discovery date. The diagram also includes information on the source record (in the PAS database). Figure 4 shows how design elements (e.g., motifs) and interpretative characteristics (e.g., deposition type) are represented in the data model. A dashed rectangle depicts an (RDF) statement that can be accompanied with information on the source (e.g., bibliographical reference, URL) that provides justification for the interpretation. The justification of a statement can be represented in RDF using an RDF 1.2 triple term (Kellogg et al. 2025), "old-style" RDF reification, or a named graph.

3.2. Model for representing design elements

In the ARCH-ON model, particular attention is paid to describing the morphological and design characteristics of objects, which inform us of their social, cultural and/or technological significance

[9]Ampulla record in the PAS database, PAS record ID SWYOR-19485D: https://finds.org.uk/database/artefacts/record/id/1038567
[10]Finna.fi record: https://finna.fi/Record/museovirasto.84B2D7270EFE764ECB6134B738F86379
[11]DCMI Metadata Terms: https://www.dublincore.org/specifications/dublin-core/dcmi-terms/
[12]FOAF Vocabulary Specification: http://xmlns.com/foaf/spec/

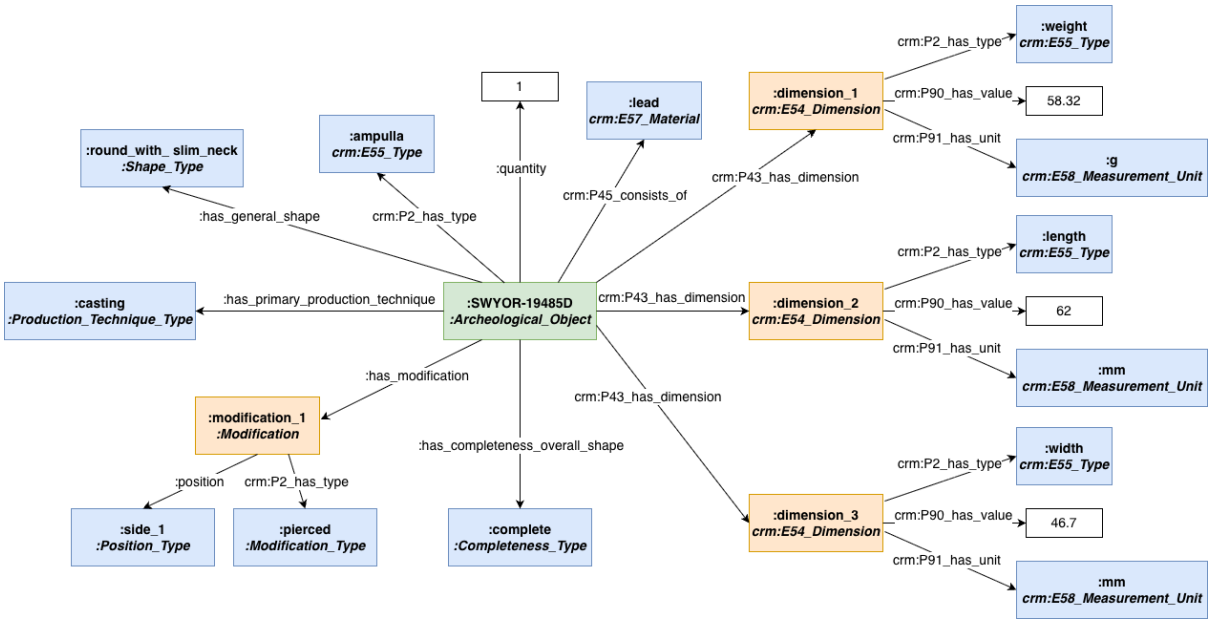

Figure 2: The ARCH-ON data model: intrinsic characteristics

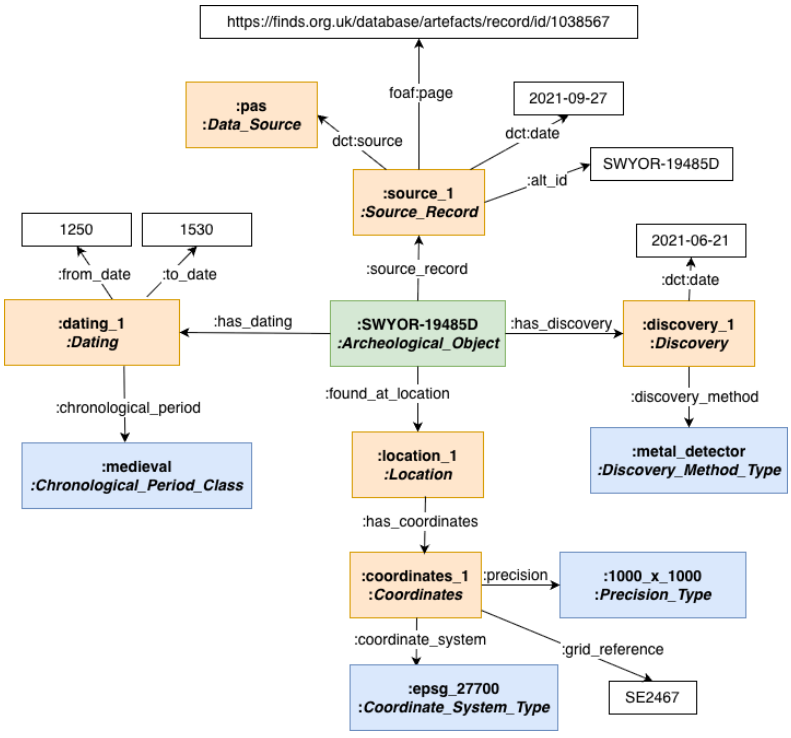

Figure 3: The ARCH-ON data model: extrinsic characteristics

and use, and which historically have been the foundation for constructing archaeological typologies. The project's goal has been to create a simple model for representing features that might be hard for the human mind to connect, but for which digital tools have the potential to reveal new patterns and connections in the data, generating hypotheses for further analysis and interpretation. This includes, as in our case, the form of ampullae and the designs on them. This model should be constructed so that it can be deployed easily for information retrieval (IR), e.g., using a SPARQL query or (in a semantic data

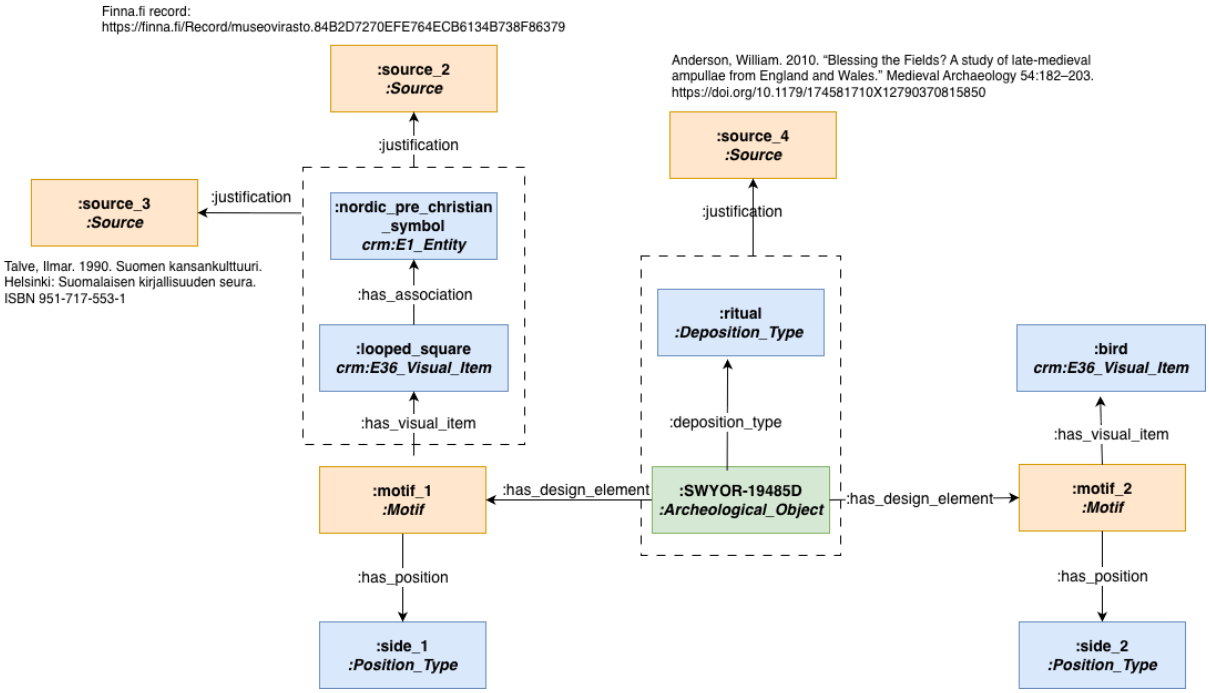

Figure 4: The ARCH-ON data model: design elements and interpretative characteristics

service interface such as the Sampo series of cultural heritage data services[13]) a built-in faceted search made easily accessible to all user groups, including those without specialist technical skills.

For this purpose, hierarchical categories of different motifs (design features) are needed. We divide these first into 'primary motifs', which can be judged (from e.g., an archaeological or cultural-historical perspective) to clearly represent one thing. These include, for example, the aforementioned "looped square" and "bird", as well as more common motifs such as a "crown", a "flower", a "heart" and different types of letters encountered on ampullae (Anderson 2010; Lewis 2025). Secondly, we have identified some ampullae have more 'complex motifs' that consist of a combination of primary motifs. For example, the letter combination "IHS"[14], "letter W, crowned"[15], or "heart, with fleur-de-lys"[16]. "IHS" is a popular Christogram referring to Jesus, whilst the two latter have been associated with the Virgin Mary and (hence) Marian cult centres, such as the Shrine of Our Lady at Walsingham, Norfolk, which was one of the most important pilgrimage sites in medieval England (Spencer 1980, Lewis 2014, 26-29).

The association between primary and complex motifs can be organized hierarchically, which facilitates category-based IR in faceted search. A complex motif is always a lower level category and has at least one additional feature in addition to its primary motif upper category. "IHS" is a lower level subcategory of each of the higher level letter categories I, H and S, since it has additional letters. Then artefacts with an "IHS" motif can be found in a faceted search by selecting any of these letters of the complex category "IHS". Similarly, "heart, with fleur-de-lys" is a subcategory of both "heart" and "fleur-de-lys".

In addition, primary motifs may have conceptual upper categories. For example, "fleur-de-lys", "quatrefoil" and "daisy-wheel" are subcategories of the motif "flower", and the letters "W", "I", "H" and "S" are subcategories of the motif "letter". This makes it easy to search for all objects with a flower motif, or all objects with letters on them, without knowing what kind of flowers or letters are used as motifs.

Moreover, a motif hierarchy can be associated with properties that tell what types are there in the

[13]Sampo model for CH data services: https://seco.cs.aalto.fi/applications/sampo/

[14]Example from the Kunera database, object no. 27635r: https://database.kunera.nl/en/collectie-object/6a47547c-ad85-47d7-8774-148805bea9a9

[15]Example from the PAS database, record ID BUC-380A5A: https://finds.org.uk/database/artefacts/record/id/1079615

[16]Example from the PAS database, record ID DENO-BD4CBD: https://finds.org.uk/database/artefacts/record/id/993744

motif. For example, “flower” motif could have a property pointing to the class “Flower” in an appropriate international ontology such as Getty-AAT. This makes it possible to link motifs to real-world phenomena and data related to it, such as books about flowers, birds, crosses, Christ and other persons, and so forth.

3.3. Ampullae as a test case for semantic modelling of archaeological finds

Ampullae are particularly suited for testing our approach. First, as noted, ampullae have been recovered in many parts of Europe, with large numbers found particularly in north-western Europe over the last few decades owing to metal detecting for archaeological items. At the time of writing (October 2025) the largest national dataset of ampullae is that of the Portable Antiquities Scheme in England and Wales (PAS[17]), which has published records of 2343 ampullae. Many other European museum and national heritage agency collections and catalogues contain records of ampullae, and the international Kunera database[18] of medieval pilgrim objects has published 1740 records of ampullae recovered across Europe through a variety of different archaeological interventions; though Kunera usually presents the obverse and reverse separately and, therefore, its record of 1740 ampullae records in practice represent fewer actual objects. Rather like coins, ampullae are a widespread and well-known (if not necessarily well-understood) archaeological object type that lends itself well to being semantically described. Considerable potential for advancing scholarship on religious material culture could be unlocked if these data resources could be better linked and connected to each other.

Second, despite the availability of finds records and the steadily increasing amount of archaeological and art-historical scholarship that has begun to accrue around ampullae (Spencer 1998, 38-72; Anderson 2010; Lewis 2025) their systematic study is difficult owing to a lack of standardized descriptions. New advances were made possible by William Anderson’s 2010 typology of English ampullae based on PAS data (Anderson 2010), but this approach also illustrates the limitations of the standard typological model. In the fifteen years since Anderson’s article the number of ampullae in the PAS database has more than quadrupled, bringing to light a variety of new designs and necessitating a reworking of the Anderson typology. Even greater work would be required to extend it to continental ampullae, and it can be questioned whether a typological structure initially based only on ampullae types recovered in one country should even be adopted at a wider scale.

Third, one of the most interesting aspects of ampullae are the motifs found on individual finds, as described above. But understanding the numerous different motif types, their combination and their relationships with other attribute data is challenging for the human mind. Moreover, some ampulla finds feature unique designs, hitherto not known from other examples. The "looped square" ampulla described above also appears to be a singular case, with no other similar examples known in the PAS database. It seems to be a foreign import to England, perhaps from the Nordic countries; its shape is similar to ampullae recovered by metal detecting in Denmark (Søvsø 2023: 422). Fitting such cases into a well-defined national typology could seem unwieldy or even counterproductive to understanding their historical contexts. Scholarly interests might be better served by semantically linking, for example, attributes such as shape and specific iconographic elements to other sources and objects, perhaps far away in other parts of Europe and the world. Updating information or reclassification would then be made much easier using the proposed semantic approach. This flexibility in enriching data is a highly relevant consideration in the context of the expanding archaeological scholarship on material culture.

Finally, ampullae are a rich source for medieval religious experience and history. To date few motifs upon ampullae have been convincingly linked to specific saints or cult centres. Rather than an inflexible typological hierarchy, describing ampullae through a semantic network (e.g., an RDF Knowledge Graph) would make it possible to study the relationship between motifs and types – as well as other attributes such as their overall shapes or regions where they have been recovered – in a considerably more nuanced manner. Our approach can therefore open new insights into the manufacture and chronology of ampullae, into inter-regional and international pilgrimage and use of ampullae as devotional objects, and into the interpretation of their religious iconography with wider art-historical implications – to

[17]PAS database: https://finds.org.uk
[18]Kunera database: https://database.kunera.nl/en/

name just a few potential research cases. Similar research questions and approaches could be deployed to the wide range of material culture that can be represented using the ARCH-ON model and approach.

4. Future potential

The preliminary proof-of-concept results of the ARCH-ON project, including an RDF knowledge graph based on ampullae data and a working demonstrator, are scheduled for publication in 2026. Future development will focus on deepening the data model, expanding it to other categories of artefactual material, and exploring the implications for interdisciplinary research, outreach and participation.

Beyond enabling harmonization between hitherto disparate artefact datasets nationally and internationally, the concept developed here of semantic artefact description and classification holds considerable potential for future data recording, data management and research, as well as publication and outreach. On a basic level, adoption of the model will allow researchers to more flexibly integrate both new artefact types as well as individual artefact attributes often overlooked in typological approaches, including materials, production techniques, aspects of artefact biographies and contexts. The greatly improved technical capabilities and accessibility of diverse scientific methods, such as compositional analysis, increases the urgency of such an approach. Furthermore, it is apparent that some sets of material culture, e.g., those stemming from larger-scale or more standardized production, are better suited for strict classification than others that are much more difficult to place within a traditional classificatory framework. By conceiving artefacts and types as clusters of attributes, semantic description allows to express relationships between intrinsic and extrinsic features in more nuanced and precise ways, thus facilitating both hypothesis- and data-driven, serendipitous research (cf. Hyvönen 2025).

More generally, ARCH-ON fits methodological and theoretical critiques on typology. While we appreciate that no KOS can inherently be entirely neutral (e.g., Hjørland 2008), the project participates in the conceptual shift away from categorical thinking in archaeology (e.g., Van Oyen 2015; Jervis 2019; Holland-Lulewicz 2025). In doing so, it forms a qualitative counterpoint to metric approaches to the analysis of material culture that similarly challenge traditional classification methods (e.g., Kafetzaki, Poblome, and Aerts 2024), and facilitates material culture studies from assemblage and network perspectives (e.g., Zedeño 2009; Beck 2018; Martin 2020; Holland-Lulewicz 2021; Tsoraki et al. 2023; Gallo and Cipolla 2023).

Finally, the ARCH-ON approach stimulates the re-use of artefact data by diverse audiences (cf. Henry, Angelbeck, and Rizvi 2017). Where traditional artefact classifications result in the attribution of artefacts to exclusive, taxonomic categories, the semantic approach makes it possible to record and examine artefact data from multitudinous angles, be they archaeological, art-historical, numismatic, technological, museological, or - beyond the academic sphere - heritage management, law enforcement and lay audiences, among others. By breaking down morphological features of objects into visually recognizable and conceptually approachable primary motifs, this approach makes it easier for non-specialized audiences to query, identify and appreciate archaeological cultural heritage. As a new concept for implementation in the research-driven collection and harmonization of archaeological artefact data, the ARCH-ON approach thus aligns with increasing calls within the Humanities and heritage disciplines specifically for Open Science and engagement with wider audiences, including citizen scientists and heritage practice communities at large (Oksanen et al. 2025; Beck and Neylon 2012; Roued, Deckers, and Thomas 2025).

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