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Strontium isotope analyses of archaeological cremated remains – new data and perspectives

Christophe Snoeck[a,b,*], Christina Cheung[a,b], Jacob I. Griffith[a,b], Hannah F. James[a,b], Kevin Salesse[c]

[a] Department of Chemistry, Research Unit: Analytical, Environmental and Geo-Chemistry, Vrije Universiteit Brussel, AMGC-WE-VUB, Pleinlaan 2, Brussels 1050, Belgium

[b] Department of Art Sciences and Archaeology, Maritime Cultures Research Institute, Vrije Universiteit Brussel, Pleinlaan 2, Brussels 1050, Belgium

[c] Department of Anthropology, Faculty of Science, Masaryk University, Kotlářská 2, Brno 611 37, Czech Republic

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A B S T R A C T

Cremated human remains are commonly found in the archaeological records, especially in Europe during the Metal Ages and the Roman period. Due to the high temperatures reached during cremation (up to 1000°C), most biological information locked in the isotopic composition of different tissues is heavily altered or even destroyed. The recent demonstration that strontium isotope ratio ($^{87}Sr/^{86}Sr$) remain unaltered during cremation and are even very resistant to post-burial alterations (which is not the case in unburned bone), opened new possibility for palaeomobility studies of ancient populations that practice cremations as a funerary ritual. This paper summarizes strontium isotopic data produced over the last decade which is then deposited on the open-access platform IsoArcH (https://isoarch.eu/) for any interested parties to use. It is the first time isotopic data on cremated remains is introduced in this database, significantly extending its impact on the scientific community.

* Corresponding author at: Department of Chemistry, Research Unit: Analytical, Environmental and Geo-Chemistry, Vrije Universiteit Brussel, AMGC-WE-VUB, Pleinlaan 2, Brussels 1050, Belgium.

E-mail address: christophe.snoeck@vub.be (C. Snoeck).

Social media: @christophe_fire (C. Snoeck), @chris_tt_cheung (C. Cheung), @JBioarch (J.I. Griffith), @ToothDetective (H.F. James), @KevinSalesse (K. Salesse)

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Specifications Table

Subject	Archaeology
Specific subject area	Stable isotope analysis Strontium Palaeomobility Landscape use Funerary practices Archaeology Anthropology
Type of data	Table Figure
How data were acquired	Collated from 24 published articles and book chapters that contained strontium isotope measurements from cremated bone fragments.
Data format	Raw
Parameters for data collection	This dataset contains strontium isotope ratios obtained on 711 calcined bones and 86 calcined teeth (dentine) from 74 European sites. $^{87}Sr/^{86}Sr$ have been measured on 608 human cremation deposits and 12 animals (some of which had several skeletal elements analysed). A total of 811 $^{87}Sr/^{86}Sr$ measurements are presented of which 724 are reported with an associated 2SE error. Strontium concentrations ([Sr]) are also available for 152 measurements. When available, the value of the SRM/NBS 987 standard used for SSB correction of the data is included.
Description of data collection	A systematic literature review was conducted using Google Scholar, Scopus and Web of Knowledge. Data from the publications released in English for Europe was collected.
Data source location	Table 1 summarizes the data source locations.
Data accessibility	Repository: IsoArcH (https://isoarch.eu/) (Salesse et al., 2017) DOI of the dataset: 10.48530/isoarch.2021.016 Direct URL of the dataset: 10.48530/isoarch.2021.016 Data is available under the Creative Commons BY-NC-SA 4.0 license.

Value of the Data

- The dataset presents all currently published $^{87}Sr/^{86}Sr$ measurements from archaeological calcined remains (n =811) in Europe. It highlights the growing importance of such type of analyses and represents a unique batch of measurements in calcined bone introduced in the IsoArcH database (Salesse et al., 2017).
- This dataset is of value to archaeologists investigating mobility in prehistoric and historical European contexts.
- Providing these data as a single dataset allows for an easy comparison of $^{87}Sr/^{86}Sr$ values for cremated remains and allows for the establishment of baseline measurements of strontium and mobility across the continent.
- The data collected here covers several parts of Europe with a focus on the Alps, the British Isles, Belgium, and Scandinavia, encompassing sites dated from the Mesolithic to the Early Middle Ages (from 5,657 BC to 975 AD). Fig. 1 has also highlighted that cremated remains from many areas are understudied, and more work is still needed to limit the current bias towards inhumations in palaeomobility studies.

1. Data Description

Strontium isotope analyses have been carried out for several decades on tooth enamel of both animal and human remains from archaeological, ecological, and forensic contexts to shed light on the possible place of origin of particular individuals. However, it is only since 2014, with the demonstration that calcined bone (bone burned at temperature above 650°C) provides a reliable substrate for strontium isotope analyses [2,3], that this type of analyses has been applied to calcined human and animal remains. While still few, the number of studies looking at cremated bones from the isotopic point of view has significantly increased, as evidenced by the data presented here compiling data from 24 scientific publications and book chapters (Table 1).

This dataset consists of 811 strontium isotope measurements ($^{87}Sr/^{86}Sr$) with 152 associated strontium concentrations ([Sr]) values. Of these $^{87}Sr/^{86}Sr$ measurements, 724 are reported with an associated 2SE error and when available, the value of the SRM/NBS987 standard used for sample standard bracketing (SSB) correction of the data is included. The $^{87}Sr/^{86}Sr$ were obtained

Table 1
Site ID (as presented in Fig. 1), Site Name, Country, Region, Closest Town and bibliographical references for the sites from which data on calcined human remains are available.

	Site Name	Country	Region	Closest Town	Refs.
1	Vollmarshausen	Germany	Hesse	Lohfelden	[6]
2	Stonehenge	United Kingdom	South West England	Amesbury	[7,8]
3	Villerup	Denmark	North Jutland	Bedsted	[9]
4	Egshvile	Denmark	North Jutland	Klitmøller	[9]
5	Erslev	Denmark	North Jutland	Mors	[9]
6	Nørhågård	Denmark	North Jutland	Snedsted	[9]
7	Ginnerup	Denmark	North Jutland	Bedsted	[9]
8	Hvidegaard	Denmark	Capital Region	Copenhagen	[9]
9	Maglehøj	Denmark	Capital Region	Krudtværket	[9]
10	Stenildgård	Denmark	North Jutland	Aars	[9]
11	Casinalbo	Italy	Emilia-Romagna	Modena	[10]
12	Scalvinetto/Fondo Paviani	Italy	Veneto	Verona	[10]
13	Narde 1	Italy	Veneto	Fratta Polesine	[11]
14	Narde 2	Italy	Veneto	Fratta Polesine	[11]
15	Szigetszentmiklós-Ürgehegy	Hungary	Central Hungary	Szigetszentmiklós	[12]
16	Herstal - Pré Wigier	Belgium	Wallonia	Herstal	[5]
17	Langford	United Kingdom	East England	Maldon	[13]
18	Oss-IJsselstraat	The Netherlands	North Brabant	Oss	[4]
19	Echt-Bocage area	The Netherlands	Limburg	Echt	[14]
20	Hastape	Belgium	Wallonia	Gouvy	[15]
21	Fosse del Haye	Belgium	Wallonia	Gouvy	[15]
22	Parknabinnia	Ireland	Munster	Kilnaboy	[16]
23	Annaghmare	United Kingdom	Northern Ireland	Crossmaglen	[17]
24	Ballymacaldrack	United Kingdom	Northern Ireland	Dunloy	[17]
25	Ballynahatty	United Kingdom	Northern Ireland	Ballynahatty	[17]
26	Clontygora	United Kingdom	Northern Ireland	Newry	[17]
27	Legland	United Kingdom	Northern Ireland	Omagh	[17]
28	Wörgl	Austria	Tyrol	Wörgl	[18]
29	Rishøj	Denmark	Jutland	Viborg	[2]
30	Fraugde	Denmark	Funen	Fraugde	[2]
31	Ribe	Denmark	Jutland	Ribe	[19]
32	Simris II	Sweden	Skåne	Simris	[20]
33	Dvorišče SAZU	Slovenia	Central Slovenia	Ljubljana	[21]
34	Archsum	Germany	Schleswig-Holstein	Archsum	[22]
35	Aubing	Germany	Bavaria	Aubing	[23]
36	Eching	Germany	Bavaria	Eching	[23]
37	Englschalking	Germany	Bavaria	Bogenhausen	[23]
38	Hofoldinger Forest	Germany	Bavaria	Otterfing	[23]
39	Obermenzing	Germany	Bavaria	Munich	[23]

(*continued on next page*)

Table 1 (*continued*)

	Site Name	Country	Region	Closest Town	Refs.
40	Waging am See	Germany	Bavaria	Waging am See	[23]
41	Flintsbach am Inn	Germany	Bavaria	Flintsbach	[23]
42	Forstinning	Germany	Bavaria	Forstinning	[23]
43	Grünwald	Germany	Bavaria	Grünwald	[23]
44	Kleinaitingen	Germany	Bavaria	Kleinaitingen	[23]
45	Gernlinden	Germany	Bavaria	Gernlinden	[23]
46	Unterhaching	Germany	Bavaria	Unterhaching	[23]
47	Langengeisling	Germany	Bavaria	Langengeisling	[23]
48	Garching an der Alz	Germany	Bavaria	Garching an der Alz	[23]
49	Kirchheim	Germany	Bavaria	Kirchheim	[23]
50	München-Residenz	Germany	Bavaria	München-Residenz	[23]
51	Konigsbrunn-Zeller	Germany	Bavaria	Konigsbrunn-Zeller	[23]
52	Poing	Germany	Bavaria	Poing	[23]
53	Trudering	Germany	Bavaria	Trudering	[23]
54	Ambras	Austria	Tyrol	Innsbruck	[23]
55	Ampaß	Austria	Tyrol	Ampaß	[23]
56	Ellbogen St. Peter	Austria	Tyrol	Tarzens	[23]
57	Fügen-Kapfing	Austria	Tyrol	Fügen	[23]
58	Hotting	Austria	Tyrol	Innsbruck	[23]
59	Kitzbühel	Austria	Tyrol	Kitzbühel	[23]
60	Mühlau	Austria	Tyrol	Mühlau	[23]
61	Mühlbachl-Matrei	Austria	Tyrol	Mühlbachl-Matrei	[23]
62	Vomp	Austria	Tyrol	Vomp	[23]
63	Wilten	Austria	Tyrol	Innsbruck	[23]
64	Kundl	Italy	Trentino-Alto Adige/Südtirol	Kundl	[23,24]
65	Moritzing	Italy	Trentino-Alto Adige/Südtirol	Bolzano	[23,24]
66	Pfatten	Italy	Trentino-Alto Adige/Südtirol	Pfatten	[23,24]
67	Latsch	Italy	Trentino-Alto Adige/Südtirol	Latsch	[23,24]
68	Eke 6:1	Sweden	Svealand	Skuttunge	[25]
69	Jönninge	Sweden	Svealand	Stavby	[25]
70	Hemlingby	Sweden	Norrland	Valbo	[25]
71	Järvsta	Sweden	Norrland	Valbo	[25]
72	Grimsta	Sweden	Svealand	Fresta	[25]
73	Valsta	Sweden	Svealand	Norrsund	[25]
74	Netphen-Deuz	Germany	North Rhine-Westphalia	Deuz	[26]

from 711 calcined bones and 86 calcined teeth (dentine), some of which were measured several times (e.g. the inner cortex and the external cortex of the petrous part – see Veselka et al. [4] for more details). The $^{87}Sr/^{86}Sr$ of the measurements included in this dataset range from 0.7066 to 0.7316 with the majority of the measurements (ca. 92%) falling between 0.7076 and 0.7136 (Fig. 2).

The bones and teeth recovered from 608 cremation deposits from which several bones (human and animal) have sometimes been analysed (e.g. Sabaux et al. [5]). It is important to talk here about cremation deposits and not individuals as, when working with cremated human remains (and commingled remains in general), it is difficult to say if all the bones belonged to a single individual or not. To account for this, the entry form of the IsoArcH database has now been adjusted. An interactive map showing the locations of all sites is also available on IsoArcH (https://database.isoarch.eu/map.php). The dataset is referenced in IsoArcH [1] under the following DOI: 10.48530/isoarch.2021.016.

The large number of funded national and international PhD, Post-Doctoral Fellowships, and scientific projects, such as the ERC Starting Grant LUMIERE (www.erclumiere.be), including strontium isotope of analyses of cremated remains further highlights the growth in this field and the importance of extracting palaeomobility information from cremated human and animal remains.

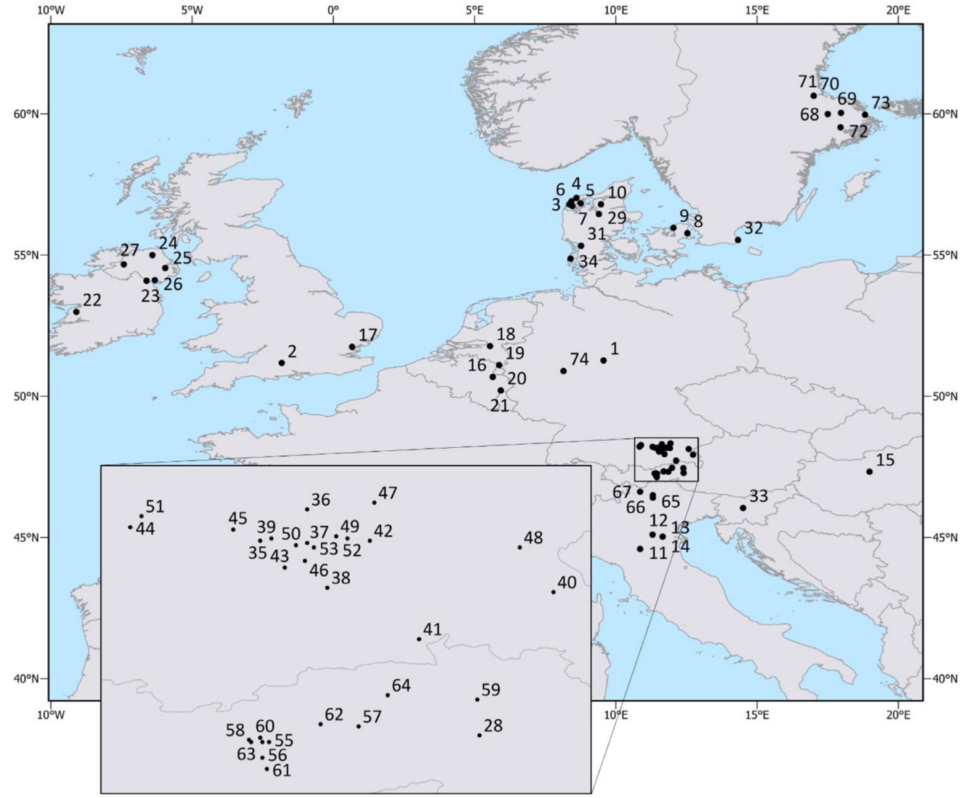

Fig. 1. Map of Europe showing the location of the sites (for a key to the site IDs please see Table 1).

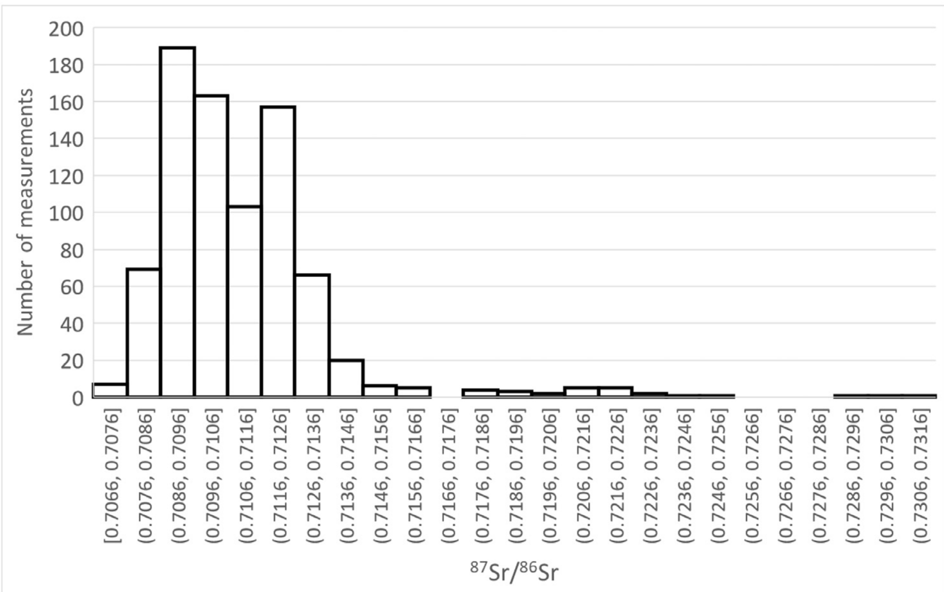

Fig. 2. Bar diagram of all the $^{87}Sr/^{86}Sr$ measurements included in the dataset.

2. Experimental Design, Materials and Methods

The European Research Council (ERC) Starting Grant LUMIERE (www.erclumiere.be) aims to understand mobility and landscape use in Europe from the Neolithic to the Early Middle Ages by bridging the gap between the number of analyses conducted in cremations and inhumations. The first step in this research project is to bring together all the currently existing Sr isotopic data on cremated remains across Europe. While still few, they represent a crucial strategic starting point to evaluate the gaps and needs to correct the current bias in palaeomobility studies towards inhumations. Indeed, it is very likely that populations practicing cremations had different origins, cultures, beliefs, etc (e.g. [17]). This means that excluding them from palaeomobility studies (and, of course, any other type of studies), limits our understanding of the past.

Data is systematically collected by searching Google scholar (https://scholar.google.com/) with keywords such as “cremations”, “cremated remains”, and “strontium isotope analysis”. Only data from European archaeological contexts are included within this dataset. Published data from modern cremated samples is excluded from this study, and studies that only published Sr concentration on cremated archaeological bone are also excluded. The final dataset is compiled from 24 published article and book chapters, and, as clearly evidenced in Fig. 1, is heavily biased towards sites in the Alps, Belgium, the British Isles, and Scandinavia. This is explained by the location of the limited numbers of labs currently carrying out this type of analyses (e.g. Brussels, Munich, Copenhagen, Durham).

Ethics Statement

This study does not involve any modern human or animal subject.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships which have or could be perceived to have influenced the work reported in this article.

Data Availability

Strontium isotope analyses of archaeological cremated remains – new data and perspectives (Original data) (IsoArcH).

CRediT Author Statement

Christophe Snoeck: Conceptualization, Methodology, Data curation, Writing – review & editing, Funding acquisition; **Christina Cheung:** Conceptualization, Methodology, Data curation, Writing – review & editing; **Jacob I. Griffith:** Conceptualization, Methodology, Data curation, Writing – review & editing; **Hannah F. James:** Conceptualization, Methodology, Data curation, Writing – review & editing; **Kevin Salesse:** Conceptualization, Methodology, Data curation, Writing – review & editing, Software.

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