GlobaLID – Global Lead Isotope Database (Version 12/2023) (https://doi.org/10.5880/fidgeo.2023.043)

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1. Licence

2. Citation

When using the data please cite:

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GlobaLID Online: https://globalid.dmt-lb.de/

3. Version history

This is an updated version of:

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A detailed changelog is provided in section 7 of this document.

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4. Data Description

This dataset is a continuously growing collection of lead isotope reference data. Lead isotopes are an established method to reconstruct the raw material provenance of archaeological objects. They are typically applied to artefacts made of copper, lead, silver, and their alloys. However, also the raw material provenance of other materials such as glass, pigments and pottery was already investigated using lead isotopes.

To successfully reconstruct the origin of the raw material, lead isotope signatures from as many as possible suitable raw material occurrences must be known. In the past, large-scaled research projects were carried out to characterise ore deposits especially in the Mediterranean area and Western Europe. However, many of these data are dispersed in the literature and were published in scientific articles or monographs. Consequently, each researcher or at least each research group had to build their own up-to-date database of reference data from the literature. To overcome these restrictions, to facilitate work with lead isotope reference data and particularly to make the data FAIR, i.e., findable, accessible, interoperable and reusable (Wilkinson et al. 2016), these published data are compiled and transferred into a uniform layout. They are further enhanced with additional metadata to facilitate their use in raw material provenance studies.

Currently, the database is restricted to ores and minerals as these are the most relevant materials for provenance studies of ancient metals. Future updates will include hitherto uncovered regions but also additional data from countries already present. Slag and other metallurgical (by-) products from ancient sites in close vicinity to ore deposits generally are a genuine representation of the ores utilised in historic times. As such, they are highly relevant for provenance studies and an extension to these materials is therefore planned.

GlobaLID is a representation of the collective work of researchers on Pb isotope studies. As such, the database is seen as a community engagement project that invites scientists all over the world to become active contributors of GlobaLID. The initiators of the database dedicate their effort to the continuation and maintenance of the database but only the support of the whole community will allow a rapid and successful growth of GlobaLID.

The most recent version of the database can be accessed on its Github repository (https://github.com/archmetalDBM/GlobaLID-database). They are regularly released as new versions and stored in this data publication. The most recent version of the database is also available through the GlobaLID web application (https://globalid.dmt-lb.de). The web application does not only allow to access the data but aims to integrate all common tasks in the workflow of the lead isotope provenance method. For these reasons, users can temporarily upload their data to compare them to the database (the file is automatically deleted from the server when the application is closed). Data from the database and uploaded by the user are shown on a map, for which different base maps are available. Furthermore, the user can select from a variety of different options (1D, 2D, 3D) for graphical representation of the data, including scatterplots, histograms or kernel density estimates. The appearance of the plots can be customised (e.g., colours and point size) but a common set of standards was set to guarantee an unbiased representation of the chosen data (e.g., no manipulation of the axis limits). The plots as well as selected portions of the database can be downloaded in different file formats. Size and resolution of the plots can be adjusted to generate publication-ready plots. A reference list of the selected data is automatically included in the download to allow proper citation. A list with the set filters also will be added to the download by default. Together with the file uploaded by the user this list allows the replication of the created plots. No user account or log-in is necessary to access the web application. Only the page for the contributors to upload new or revised data is password protected to avoid spam.

1.1. Origin of data

All lead isotope values and directly related metadata, when available, were extracted from the publications cited in the column "Reference". Other publications were consulted to provide additional metadata. These are listed in the column "Additional references".

1.2. Data processing/Compilation of data base

Additional to the data extracted from the literature, the following procedures were applied to ensure the comparability of the lead isotope data and to enrich the datasets with additional metadata.

<u>Geographical metadata:</u>

Coordinates of the sample location were taken from the respective references, if included. If not, they were reconstructed by the following procedures:

- Georeferencing of maps included in the publications with QGIS
- Searching literature publications and browsing sources on the internet (mindat.org, openstreetmaps.org, …) for location and especially mineral occurrences, deposits, or mines with the same or very similar names
- In case neither of the two above mentioned methods allowed a clear localisation of the sample location, coordinates approximated to the most likely location or coordinates from the next larger securely identifiable geographical or political unit (e.g., province) are given. If the coordinates were obtained this way, the criteria used for the approximation are given in the column "Location precision".

Based on the coordinates, modern countries, and administrative units (province/state, county) were added via reverse geocoding with the nominatim API of OpenStreetMap (https://nominatim.org).

<u>Lead isotope ratios and model age parameters:</u>

The specific lead isotope ratios given in publications might differ. Most notably, geological publications prefer to publish isotope ratios normalised to ^{204}Pb while especially older archaeological publications preferentially supplied ^{206}Pb-normalised ratios. Publications in environmental geochemistry in contrast typically use $^{206}Pb/^{207}Pb$ in combination with $^{208}Pb/^{206}Pb$. Hence, the database contains eight different lead isotope ratios to cover all common representations. All ratios not given in the respective publications were calculated with an R script from the available ones to ensure concise data.

Additional to the lead isotope ratios, lead isotope age models become increasingly popular as an additional way to investigate lead isotope data. The database contains age model parameters according to the models of Stacey and Kramers (1975), Cumming and Richards (1975), Albarède and Juteau (1984) and Albarède *et al.* (2012). The more accurate estimate of Goldmann et al. (2015) was used for all models. For each model, R scripts were used that implemented the calculations outlined in the respective publications. All parameters were calculated with these scripts to ensure comparability and age model parameters given in the original publication were discarded.

Data accuracy and precision:

Data quality is controlled by the methodological setup, i.e., the instrument and raw data correction applied. Analysis carried out by TIMS before 1974 produced inaccurate data due to the analytical setup (the sample-filament technique) and correction of the mass bias based on the measurement of reference material (typically NBS 981), which was not necessarily run in precisely the same conditions of purity and temperature as the samples. Double- and triple-spike techniques (Hamelin *et al.*, 1985; Galer, 1998) improved the precision and accuracy of Pb isotope measurements of reference material by one to two orders of magnitude. The introduction of multi-collector inductively coupled plasma mass spectrometry (MC-ICP-MS) for the measurement of lead isotope ratios using an external Tl standard increased the analytical throughput without affecting data quality (e.g. White *et al.*, 2000). Today, multi-collector mass spectrometer systems with thermal ionisation using double spike (TIMS) or ionisation by inductively coupled plasma (MC-ICP-MS) deliver the highest precision. Analysis of lead isotopes by quadrupole (Q) or single-collector (SC) ICP-MS, partially coupled to laser ablation (LA) units for spatially resolved measurements, necessitates a careful analytical protocol and even then it is able to produce data with an at best moderate resolution according to state-of-the-art standards (McFarlane *et al.*, 2016) due to poor peak shape and low transmission. The database of GlobaLID can be filtered according to the instrument used and the analysis/publication year of the data in the respective columns.

5. Frequently Asked Questions

1. The samples don't have sample numbers associated with them. How should I label those so that they are identifiable?

If the samples are published, format the samples with a short citation and a running number that you assign to each sample. The format for this is as follows:

- One Author: LastName_1
- Two Authors: FirstAuthorLastname_and_SecondAuthorLastname_1
- Three or more authors: FirstAuthorLastname_et_al_Date_1
  Example: Ulrych_et_al_1967_1

2. I want to submit lead isotopic data for a geological deposit, but I know it was not mined by archaeological communities. Should I bother submitting it?

Yes. You can add this detail in the "Reason" category associated with the "Archaeologically Relevant (Y/N)" column. One use for data such as this would be to help characterise the geological district that hosts this deposit. Perhaps there are known archaeological mines within that district, and this data could serve as a stand-in if there is no existing data from those mines. We also hope that this database will be of use to geologists, so we encourage an inclusive practice, where all data is submitted regardless of whether it is relevant to archaeologists or not.

Example: Haest et al. (2010) published lead isotopic data on ore minerals from the Kundelungu Plateau in the Democratic Republic of the Congo (DRC). There are no known precolonial mines in this area, but the Kundelungu Plateau is part of the Lufilian Fold belt in the DRC and Zambia which also hosts the Central African Copperbelt. Therefore, these data could help understand lead isotopic patterning for known precolonial mines in the Copperbelt (of which there are hundreds). For submission to GlobaLID, the "Archaeologically Relevant (Y/N)" column was marked "N", and the following statement was added to the "Reason" column: "Relevant only to help understand the distribution of data for the Lufilian fold belt (including other parts of the Central African Copperbelt). No evidence of precolonial mining in this area."

3. What details should I list in the "Reasons" category associated with "Archaeologically Relevant (Y/N)"?

Ideally, this should be a detailed reason as to why the data is or is not archaeologically relevant, so that any potential users know how to use this data. There are a number of ways to approach this:

- You could use citations to direct the user to a publication detailing why a deposit is relevant for archaeological applications, or why it is not.
  Example: "See Bisson, M.S., 1976. The prehistoric copper mines of Zambia. University of California, Santa Barbara."
- You could give detailed responses about the geological context for the geological deposit or geological district
  - Example: Archaeologically Relevant: "N"; Reason: "Currently no evidence for precolonial exploitation of copper in the Barberton Greenstone Belt. Historically it was also a much more important source for gold."
  - Example: Archaeologically Relevant: "N"; Reason: "Currently no evidence for precolonial exploitation"
  - Example: Archaeologically Relevant: "Y"; Reason: "No evidence for precolonial exploitation at the deposit, but gives a signature for the district, which does have evidence for precolonial exploitation. See Friede, H.M., 1980. Iron Age mining in the Transvaal. Journal of the Southern African Institute of Mining and Metallurgy, 80(4), 156-165." (See the above question for further information about this example)
  - Example: Archaeologically Relevant: "N"; Reason: "Covered by up to 100m of Kalahari Sands. Modern mining district"
- You could also give a detailed response as to when the specific deposit/district becomes relevant:
  Example: Archaeologically Relevant: "Y"; Reason: "Archaeologically relevant after the 18th century CE, per Orton, J., 2014. The late pre-colonial site of Komkans 2 (KK002) and an evaluation of the evidence for indigenous copper smelting in Namaqualand, southern Africa. Azania: Archaeological Research in Africa, 49(3), 386-410."

4. I want to submit unpublished data that I have collected. What should I list in the "Year" and "Reference" columns?

We welcome the submission of unpublished data, and will work with you to publish this data in an appropriate data journal, so that it has a full reference and DOI associated with it and can be cited in future studies. For the spreadsheet submission, please put "Unpublished" in the "Year" Column, and your last name in the "Reference" column. This will then be updated once the data have been published in the data journal.

6. File description

6.1. File inventory

File name	File format	Content
GlobaLID	.csv	Lead isotope database of ore and ore minerals.
calculate_model_ages	.R	R script to calculate the parameters of the lead isotope age models.
calculate_ratios	.R	R script to calculate missing lead isotope ratios.

6.2. Description of GlobaLID.csv

The file parameters are:

- Separator: "," (comma)
- Decimal sign: "." (dot)
- Quote: double quote
- File encoding: UTF-8

The following notations apply to multiple columns:

- Semicolons ";" separate multiple entries in the same field.
- Where available, local names or titles in their respective script are given in square brackets "[ ]" after their English equivalents

Column header	Description
Country	The today's country the sample location is situated in.
Political province/region	The today's political province, region, or similar administrative unit the sample location is situated in.
County	The country or similar administrative unit the sample location is situated in.
Mining area	The superordinate area the mining site is located in as defined in the original publication or other publications related to the same geographical area.
Mining site	The specific sampling location.
Add. information on mine	Additional information about the sampling location (e.g. exact mine shaft, collected from tailings), if specified in the original publication.
Latitude	The geographical coordinates of the sample location or their approximation according to EPSG 4326 (WGS84, compatible with GoogleMaps and OpenStreetMap).
Longitude	
Location precision	Exact – securely identified location; Exact/neighbouring – identified location with minor uncertainties, e.g. within the same mining field; Placeholder coordinates – original location not identifiable, placeholder coordinates at the next larger securely identifiable geographical or political unit (e.g. village with the same name, at a central position within the county)
Tectonic/geolog. super unit	The geological super unit is the globally most superordinate unit of a locality. Geological unit and subunit each describe
Tectonic/geolog. unit	

Tectonic/geolog. subunit	subsequent lower level subdivisions of the super unit down to a regional level. Fields were left blank if the respective subdivisions do not exist.
Deposit type	The metallogenetic type of the deposit.
Mineralisation Style	The morphology of the ore deposit from which the sample was derived, either supplied in the original publication or derived from additional literature sources.
Metals	The metals that can be theoretically produced from the ores. This does not necessarily mean that all metals given here were also necessarily extracted and the produced metal(s) may be subject to changes over time.
Minerals	The ore minerals the sample consists of.
Sample number	The identifier of the sample according to the respective publication. If not specified in the original publication, the data were consecutively numbered according to their ordering in the publication's data table.
Geol. period	The geological age/epoch at which the ore body formed (either supplied in the original publication or derived from additional literature sources). If known whether this specifies the ore or the host rock, this information is provided in parentheses, e.g. "Devonian (host rock)" or "350-400 Ma (ore)".
206Pb/204Pb	Lead isotope ratios of the sample.
207Pb/204Pb	
208Pb/204Pb	
206Pb/207Pb	
208Pb/207Pb	
204Pb/206Pb	
207Pb/206Pb	
208Pb/206Pb	
Model_Age_SK75	The model age according to the lead isotope age model of Stacey and Kramers (1975)
mu_SK75	The µ value according to the lead isotope age model of Stacey and Kramers (1975)
kappa_SK75	The κ value according to the lead isotope age model of Stacey and Kramers (1975)
Model_Age_CR75	The model age according to the lead isotope age model of Cumming and Richards (1975)
mu_CR75	The µ value according to the lead isotope age model of Cumming and Richards (1975)
kappa_CR75	The κ value according to the lead isotope age model of Cumming and Richards (1975)
Model_Age_AJ84	The model age according to the lead isotope age model of Albarède and Juteau (1984)
mu_ AJ84	The µ value according to the lead isotope age model of Albarède and Juteau (1984)
kappa_ AJ84	The κ value according to the lead isotope age model of Albarède and Juteau (1984)

Model_Age_ADB12	The model age according to the lead isotope age model of Albarède *et al.* (2012)
mu_ADB12	The μ value according to the lead isotope age model of Albarède *et al.* (2012)
kappa_ADB12	The κ value according to the lead isotope age model of Albarède *et al.* (2012)
Instrument used	The instrument used to measure the lead isotope ratios.
year	If available, the year of the analysis. Otherwise the publication year of the sample.
2s_206Pb/204Pb	2σ standard deviation of the respective lead isotope ratios of the sample.
2s_207Pb/204Pb	
2s_208Pb/204Pb	
2s_207Pb/206Pb	
2s_208Pb/206Pb	
Archaeologically Relevant? (Y/N)	Evidence for archaeological/historical exploitation of the district, restricted to "yes" (it is present) or "no" (it is absent). Additional explanation might be provided in the column "Reason_archaeologically_relevant"
Reason_archaeologically_relevant	Reasoning, source or additional information about the archaeological/historical exploitation of this deposit.
doi	The DOI of the publication in which the lead isotope ratios of the sample were first published.
Reference	Complete bibliographic reference of the publication the lead isotope ratio of the sample was published in. If several references exist for the exact same dataset, only the oldest primary reference is given.
Note	Additional important information to the lead isotope date like ratios with high analytical uncertainties.
Additional references	Full references of publications used to provide information to the data in addition to the original publication.

7. Changelog

Version	Release date	Changes
12/2023	2023-11-20	GlobaLID.csv • Definition and inclusion of additional metadata o Mineralisation Style o 2s_206Pb/204Pb o 2s_207Pb/204Pb o 2s_208Pb/204Pb o 2s_207Pb/206Pb o 2s_208Pb/206Pb o Archaeologically Relevant? (Y/N) o Reason_archaeologically_relevant o Additional references • Inclusion of 861 additional entries in already covered regions • Inclusion of new regions in

		◦ Europe (Germany, Czech Republic; 632 entries) ◦ Africa (several countries, 661 entries) ◦ South America (Argentina, 101 entries) • Minor editing of existing entries to increase consistency (e.g., capitalisation, harmonisation of British and American English) Calculate_ratios.R: • Improved detection pattern of lead isotope ratios Data description: • Inclusion of use cases (new chapter 4) • Updated documentation of GlobaLID.csv to include new metadata and refined definition for "Geol. period" • Updated Database reference list (new chapter 8) DOI Metadata • Additional authors and contributors • Change of affiliations for some authors
1.0	2021-09-01	Initial release of the database

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