World Atlas of late Quaternary Foraminiferal Oxygen and Carbon Isotope Ratios

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Abstract. We present a global atlas of downcore foraminiferal oxygen and carbon isotope ratios available at https://doi.org/10.1594/PANGAEA.936747~~https://doi.pangaea.de/10.1594/PANGAEA.936747~~ (Mulitza et al., 2021). The database contains 2,106 published and previously unpublished stable isotope downcore records with 361,949 stable isotope values of various planktic and benthic species of Foraminifera from 1,265 sediment cores. Age constraints are provided by 6,153 uncalibrated radiocarbon ages from 598 (47%) of the cores. Each stable isotope and radiocarbon series is provided in a separate netCDF file containing fundamental meta data as attributes. The data set can be managed and explored with the free software tool PaleoDataView. The atlas will provide important data for paleoceanographic analyses and compilations, site surveys, or for teaching marine stratigraphy. The database can be updated with new records as they are generated, providing a live ongoing resource into the future.

1 Introduction

Stable oxygen and carbon isotope ratios measured on foraminiferal shells are often regarded as the foundation of Marine Geology and Paleoceanography. The importance of these proxies stems from their broad applicability in time and space, their established and efficient analytical methods and their great value for stratigraphy and paleoceanographic reconstructions (see review by Pearson, 2012). Since the pioneering work of (Urey, 1947), millions of foraminiferal isotope measurements have been performed representing time slices from the Middle Jurassic (e.g. Vetoshkina et al., 2014) into the Anthropocene (e.g, McGregor et al., 2007). Foraminiferal isotopes have substantially contributed to the reconstruction and understanding of the global climate evolution since the Early Cretaceous (Cramer et al., 2009) including the validation of the orbital theory of the ice ages (Hays et al., 1976), reconstructions of ice volume (Shackleton and Opdyke, 1973; Waelbroeck et al., 2002) and water mass structure, ocean circulation and carbon cycling (Curry et al., 1988; Duplessy et al., 1988; Boyle and Keigwin, 1987).

Despite their importance for the understanding of the Earth System, foraminiferal isotope data have not been systematically catalogued globally or stored in a database in a consistent and standardized format. Foraminiferal isotope data are usually available in arbitrary data formats and scattered across different data repositories, which hinders an automated analysis. Harmonized data collections have the advantage that (i) information about data coverage can be immediately accessed and visualized, for example in the planning phase of research projects, (ii) data can be quickly compared for verification/quality control or to separate local signals from global signals and (iii) that customized software can be used to visualize and analyse the data.

Here we present the first global atlas of foraminiferal stable isotope data (with uncalibrated radiocarbon ages where available). The data are stored in netCDF format (Rew and Davis, 1990) and can be directly analysed and visualized with the free software tool PaleoDataView (PDV, Langner and Mulitza, 2019). In PDV, age information for a specific sediment core is linked to any downcore proxy series imported for that core within the same collection. This strategy ensures the long-term maintainability and consistency of the age models across different proxy records (e.g. stable isotope records of different species) in the same collection. The netCDF format also allows the data to be analysed using programming languages such as MATLAB, R, Fortran, C++ and Python.

2 Data sources and harmonisation

The database is provided as a collection of 2,106 netCDF files with $\delta^{18}O$ and $\delta^{13}C$ data of species-specific foraminiferal carbonate and 598 netCDF files with raw radiocarbon ages (see references in Table A1). A detailed description of the attributes and variables in the netCDF files is provided in Supplements S1 and S2. About 79% of the files containing stable isotope records were derived from data downloaded either from PANGAEA (www.pangaea.de) or NOAA's National Centers for Environmental Information (NCEI, www.ncdc.noaa.gov). The remaining 21% of the stable isotope files are based on data obtained directly from a stable isotope laboratory by one of the co-authors (8%), or have been digitized from tables provided in papers, or paper supplements (6%), or through personal communication (7%). Radiocarbon data are not as frequently archived in public databases as stable isotope data. Only 62% of the files containing radiocarbon data were obtained from NOAA or PANGAEA, whereas data in 32% of the files were copied from tables in papers or paper supplements. 5% of the files are based on data directly obtained from laboratories, while only 1% was obtained through personal communication. The data set also includes 105 previously unpublished species-specific stable isotope downcore records including both $\delta^{18}O$ and $\delta^{13}C$ values and 45 species-specific isotope downcore records for which either $\delta^{13}C$ or $\delta^{18}O$ was previously unpublished (Supplement S3). An Excel spreadsheet containing all data sources is available from Zenodo (https://doi.org/10.5281/zenodo.5552329~~https://zenodo.org/record/5552329~~).

To generate the netCDF files, meta data, isotope data and radiocarbon ages (if available) were first assembled in species- and site-specific Excel files in the format required by PDV. The species names were preserved as used in the original publication. If more than one stable isotope record of the same species was available for the same core, we added a suffix (e.g., size class or version) to the species name. The Excel files were then edited for units (mainly conversion from “cm” to “m” and years to kiloyears) and meta data were added. Unavailable data fields were filled with “NaN”. Finally, the Excel files were converted to netCDF files using the PDV import tool. Stable isotope data and radiocarbon data were saved in separate files to allow the radiocarbon file to link to several proxy records from the same core via the core label. After import, the data were inspected and quality controlled in PDV. Every row of the downcore data fields is associated with a “use-flag” indicating whether the values should be included in an analysis (use flag = 1) or not (use flag = 0). This flag can be used to exclude outliers (e.g. due to turbidites) or radiocarbon reversals in a later analysis of the data, while maintaining the original data in the file. Isotope values without replicates were imported with a use-flag set to “1”. For replicate stable isotope measurements the use flags were set to “0” and an average of the replicates (use flag = 1) was added to the series with a comment “Mean of multiple measurements” in the same row. Raw radiocarbon ages were generally imported with a use-flag set to “0” since the data are uncalibrated. Most of the data are archived with original downcore depth of the samples. If a composite depth scale was used (e.g., for International Ocean Discovery Program (IODP) and its predecessors Deep Sea Drilling Program (DSDP) and Ocean Drilling Program (ODP) cores), a comment was added and care was taken that available radiocarbon dates were imported on the same depth scale. The data is stored as raw data, with all documented corrections removed from the data. This includes a previously subtracted reservoir age and corrections applied to the stable isotope values (e.g., to account for species offsets). Variables to store downcore radiocarbon reservoir and stable isotope corrections that may be applied to the data at a later stage are already included in the netCDF files. These variables have been imported with default values of 0.4 ka (± 0.1) for all radiocarbon reservoir ages and a stable isotope correction of “0” for all oxygen and carbon isotope ratios. Both reservoir ages and stable isotope corrections can be edited within PDV.

3 Data distribution

3.1 Spatial and vertical coverage

Stable isotope records are available from all major ocean basins (Fig. 1), but tend to cluster along continental margins, where higher sedimentation rates, and thus higher temporal resolutions, can be found compared to mid-ocean ridges or deep abyssal basins. About 65% of the downcore records are from coring locations within 400 km of the coastline (Fig. 2). The deepest record in the atlas is from 5,105 m water depth (EN066-29PG, eastern tropical Atlantic (Curry and Lohmann, 1983), the shallowest record from 50 m water depth (GeoB9503-5, Senegal Mudbelt, Mulitza, unpublished). However, the availability of records decreases in waters shallower than about 400 m (Fig. 3), where more dynamic sedimentation regimes exist, and below 3800 m due to carbonate dissolution which often prevents the production of reliable, continuous foraminiferal stable isotope records.

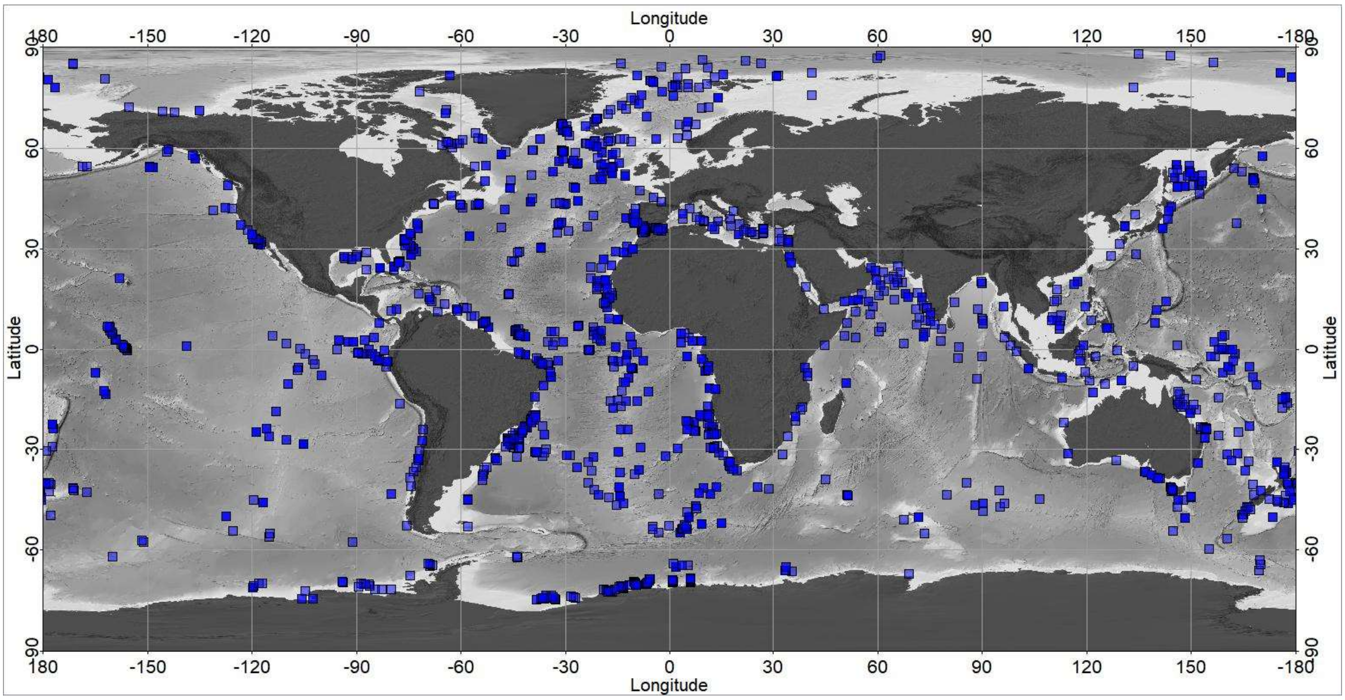

Figure 1: Spatial distribution of stable isotope records available in this atlas. The map has been generated with PaleoDataView (Langner and Mulitza, 2019).

Records are available in all oceanic 5° latitude bands with the highest number in tropical latitudes and decreasing numbers towards high latitudes (Fig. 3). This pattern is likely the result of the year-round accessibility of low latitudes compared to high latitudes where, due to sea ice cover or harsh weather conditions in the cold season, expeditions are often constrained to the warm season. The largest fraction (~47%) of the stable isotope records was measured on material from the Atlantic whereas about 9% are from the Southern Ocean (Fig. 4). However, with 21 cores/million km^2, the Mediterranean has the highest density of cores followed by the Arctic Ocean (7.8 cores/million km^2) and the Atlantic (7.5 cores/million km^2). The Pacific and Indian Oceans are currently only covered by 2 and 2.1 cores/million km^2, respectively, which is likely a result of relatively low accumulation rates and poor carbonate preservation over large areas. In addition, the retrieval of sediment cores in the remote and deep central areas requires more ship time compared to the Atlantic and Mediterranean Sea.

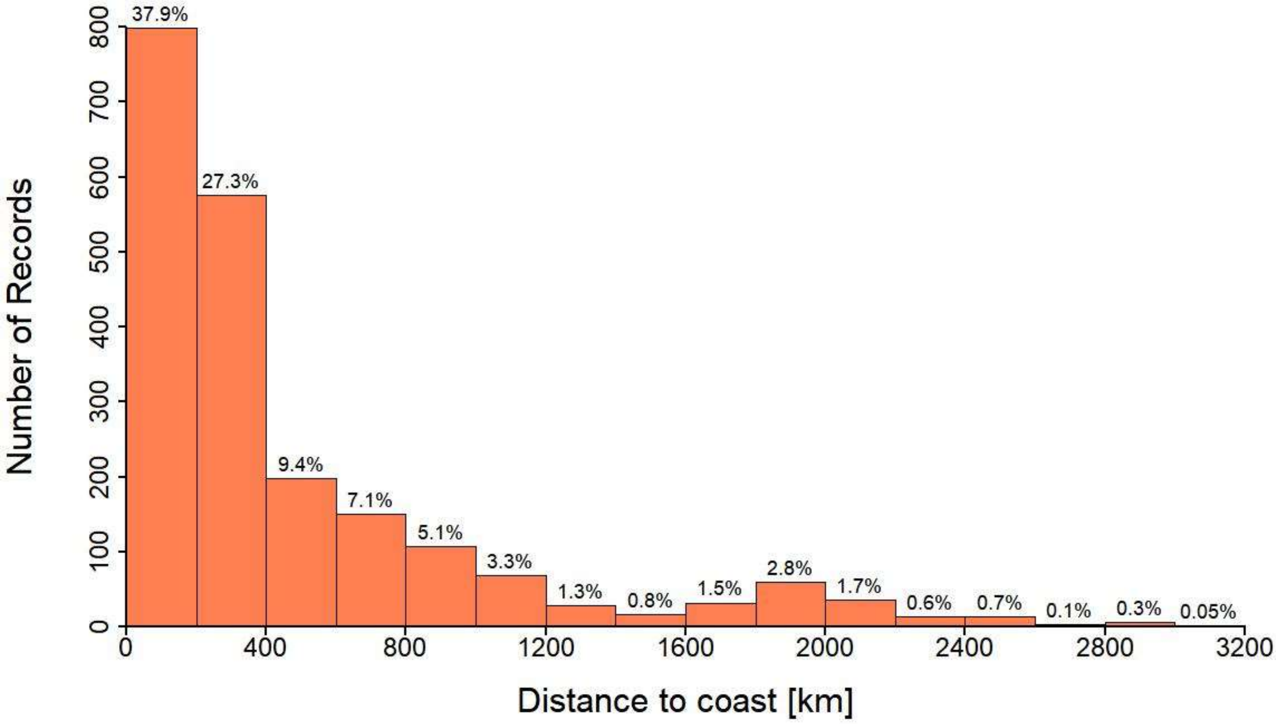

Figure 2: Number of isotope records available in this atlas versus distance to the coastline in 200 km bins. The global coastline was created with the free vector and raster map data from www.naturalearthdata.com.

3.2 Species distribution

The majority (61%) of all stable isotope values available in this compilation were measured on planktic Foraminifera (see individual percentages for carbon and oxygen isotopes in Fig. 5). Among the planktic species, *Globigerinoides ruber* (37%) and *Neogloboquadrina pachyderma* (28%) are the most commonly used species, followed by *Globigerina bulloides* (17%) and *Trilobatus sacculifer* (6%). These species have a relatively broad geographical coverage and are considered as mixed-layer species in their respective environment (Schiebel and Hemleben, 2017). Isotope measurements on other planktic species (summarized under "other planktics") constitute about 12% of all values in the atlas (Fig. 5). 75% of the included planktic oxygen isotope values and 88% of the included benthic oxygen isotope values are reported together with the corresponding carbon isotope value. Most of the benthic isotope values (70%) were obtained from species of the genus *Cibicides/Cibicidoides*. Isotope values from the in-faunal genus *Uvigerina* constitute about 18% of all benthic isotope values in the atlas. The grouping of the original species names into species/genus names used in Fig. 5 and Fig. 6 is provided in Supplement S4.

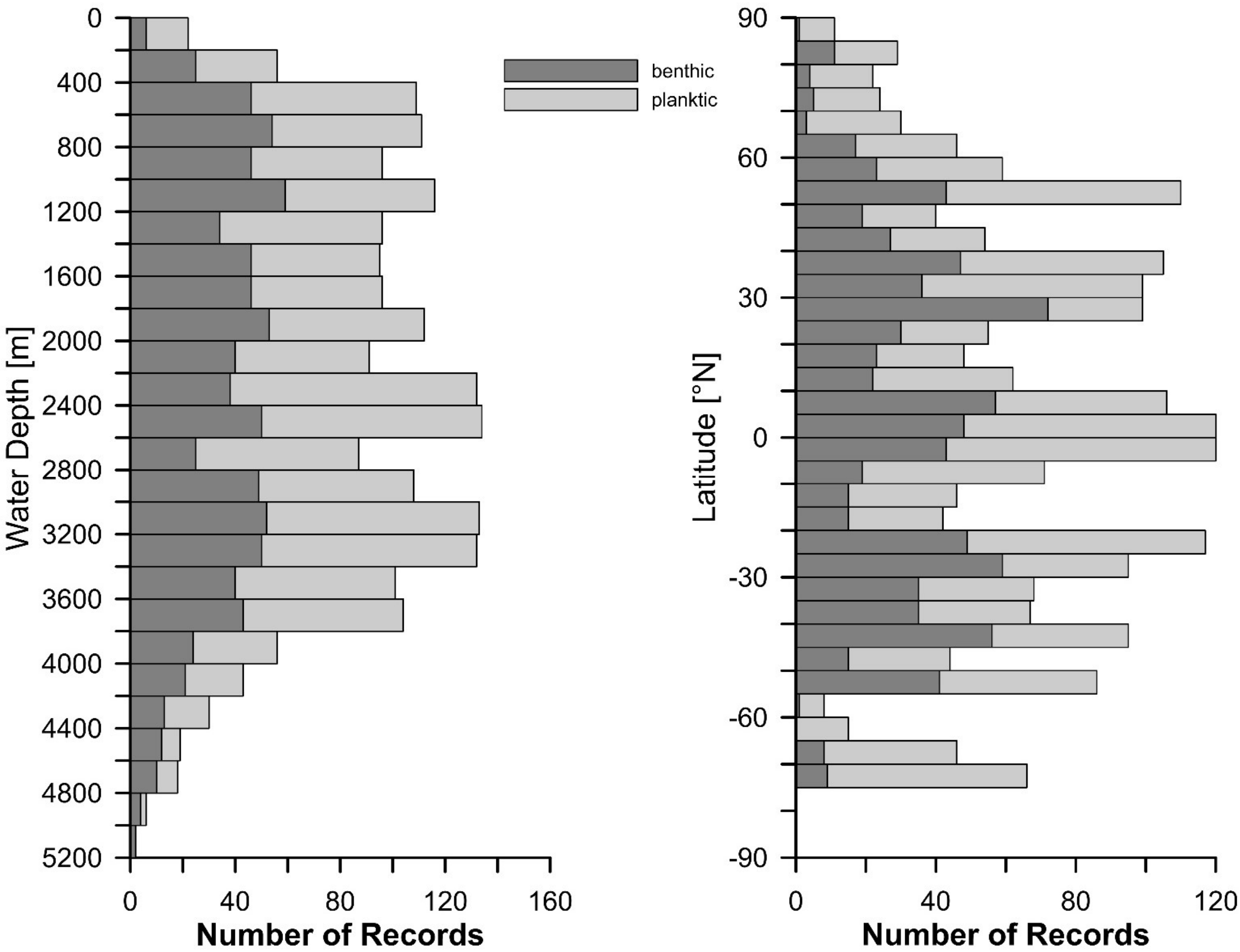

Figure 3: Distribution of stable isotope records with water depth in 200 m bins (left) and with latitude in 5° bins (right).

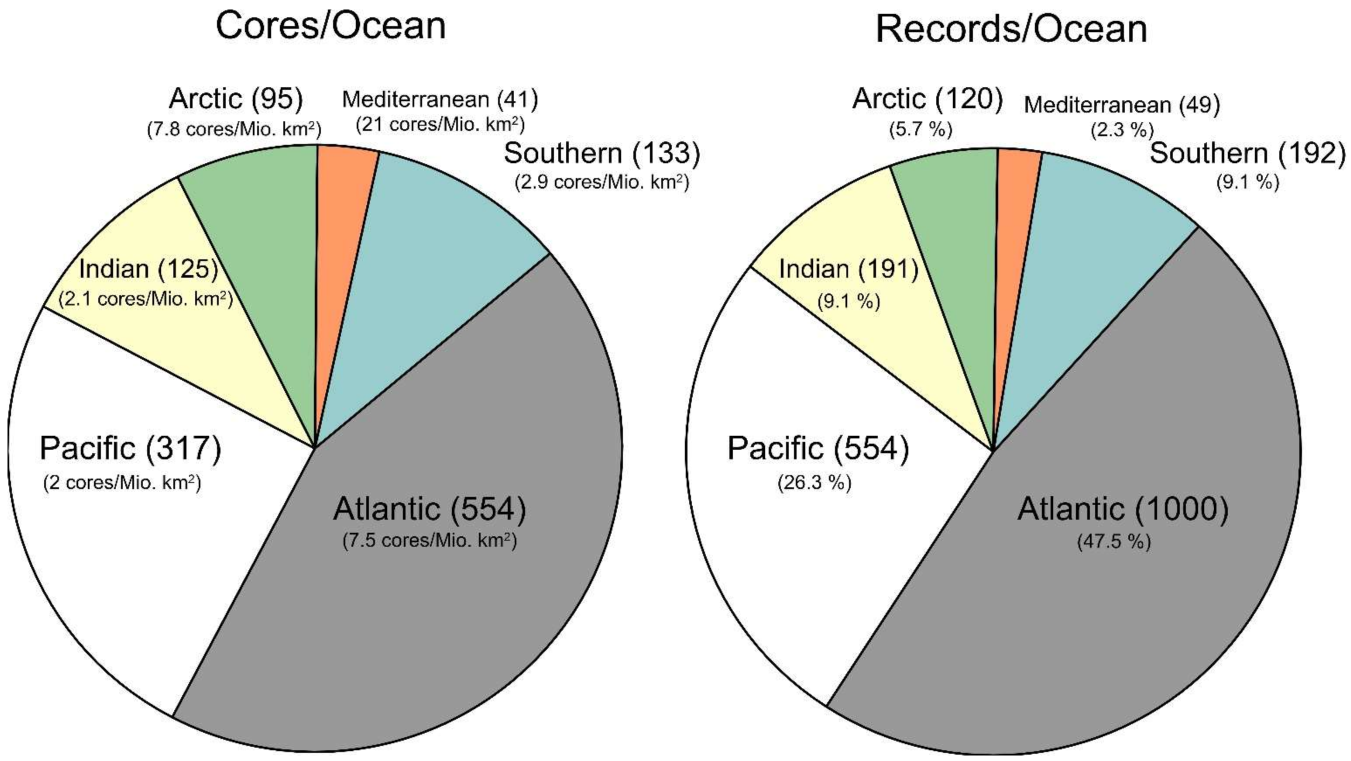

Figure 4: Number of cores (left) and records (right) for major ocean basins. A record is a downcore series of paired oxygen and carbon isotope measurements on a foraminiferal species or species group stored in a single netCDF file. Several records can exist for a single core. The counts include records/cores for which either $\delta^{18}O$ or $\delta^{13}C$ is missing. Numbers in small font below ocean basin name indicate density of cores in cores/10^6 km^2 (left) and percentage from the total number of records in the atlas (right) in each basin. Ocean basins follow the definitions in the World Ocean Atlas 2001 (Stephens et al., 2002). Pacific includes the Sea of Japan and the Indian Ocean includes the Bay of Bengal and the Red Sea.

3.3 Species-specific and latitudinal distribution of oxygen and carbon isotope values

In the current version, the atlas contains a total of 201,593 $\delta^{18}O$ values. The lowest $\delta^{18}O$ value (-7.51 ‰) is observed in the species *G. ruber* white (Fig. 6) from the Gulf of Mexico core LOUIS1924 under the influence of Mississippi freshwater discharge (Aharon, 2003). The highest planktic $\delta^{18}O$ value (6.31 ‰) can be observed in the tropical species *G. ruber* from core M31_2-78_PC6 (Red Sea, Geiselhart and Hemleben, 1998a). With latitude, planktic $\delta^{18}O$ values follow the typical bell-shaped curve as expected from a dominant influence of sea surface temperature (Fig. 7). Benthic $\delta^{18}O$ values range from -2.85 ‰ from *Cibicides corpulentus* in core OC205-2-108GGC from the western tropical North Atlantic (Slowey and Curry, 1995) to 5.9 ‰ from *Uvigerina bifurcata* from South Atlantic site JR244-GC528(Roberts et al., 2016). Vertically, the $\delta^{18}O$ of benthic foraminiferal species increases with water depth over the upper 800 m as expected from decreasing temperatures within the main thermocline (Fig. 8). Planktic δ^{18}O values do not show clear visual trends with water depth (not shown). Planktic and benthic δ^{18}O values converge towards polar regions as expected from the decreasing temperature stratification with increasing latitude (Fig. 7).

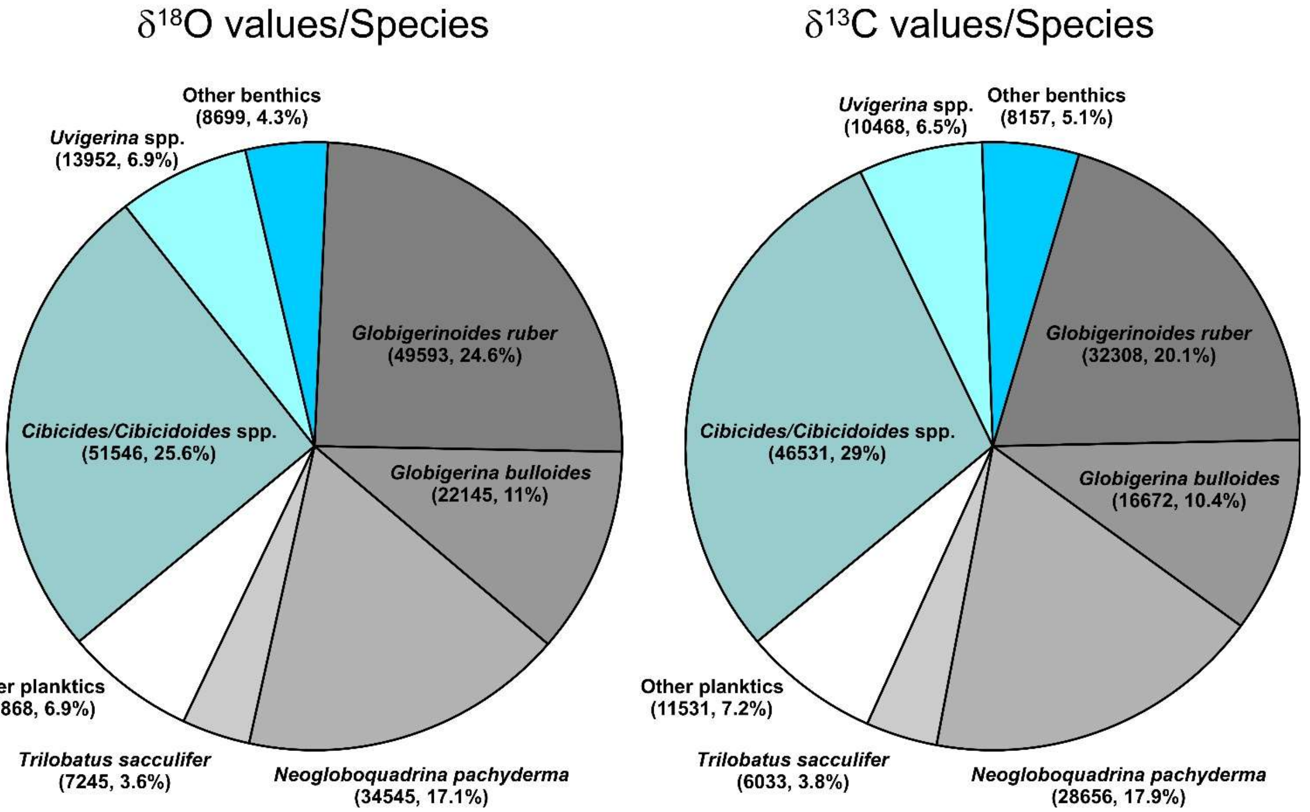

Figure 5: Fraction of oxygen (left) and carbon (right) isotope values measured on benthic (blue) and planktic (grey) species/species groups. Numbers below the species/genus names indicate absolute number of values and percentage from the total number of δ^{18}O (left) or δ^{13}C (right) values in the atlas. See Supplement S4 for the categorisation of the individual species names from the original publications.

The data set contains 160,356 δ^{13}C values. Planktic Foraminifera from tropical latitudes show the highest δ^{13}C values (Fig. 7) of up to 3.53 ‰ in shells of the species *G. ruber* from the Red Sea core M31_2-78_PC6 (Geiselhart and Hemleben, 1998). Planktic δ^{13}C values get as low as -17.7 ‰ on *N. pachyderma* sinistral (Fig. 6) in core LV28-4-4 from the Sea of Okhotsk (Kaiser, 2001), which might be related to a potential contribution from authigenic carbonate minerals that form with the anaerobic oxidation of methane (Cook et al., 2011). Benthic foraminiferal δ^{13}C gets as low as -7.99 ‰ in *Elphidium batialis* from western North Pacific core KT90-9_21 (Oba and Murayama, 2004) and as high as 3.36 ‰ in the aragonitic shells of *Hoeglundina elegans* from western North Atlantic core OC205-2-149JPC(Slowey and Curry, 1995). Benthic species of the genus *Cibicides/Cibicidoides* show a clear trend toward decreasing $\delta^{13}C$ values in the deep ocean (Fig. 8), as expected from the global distribution of $\delta^{13}C$ in dissolved ΣCO_2 (Kroopnick, 1985).

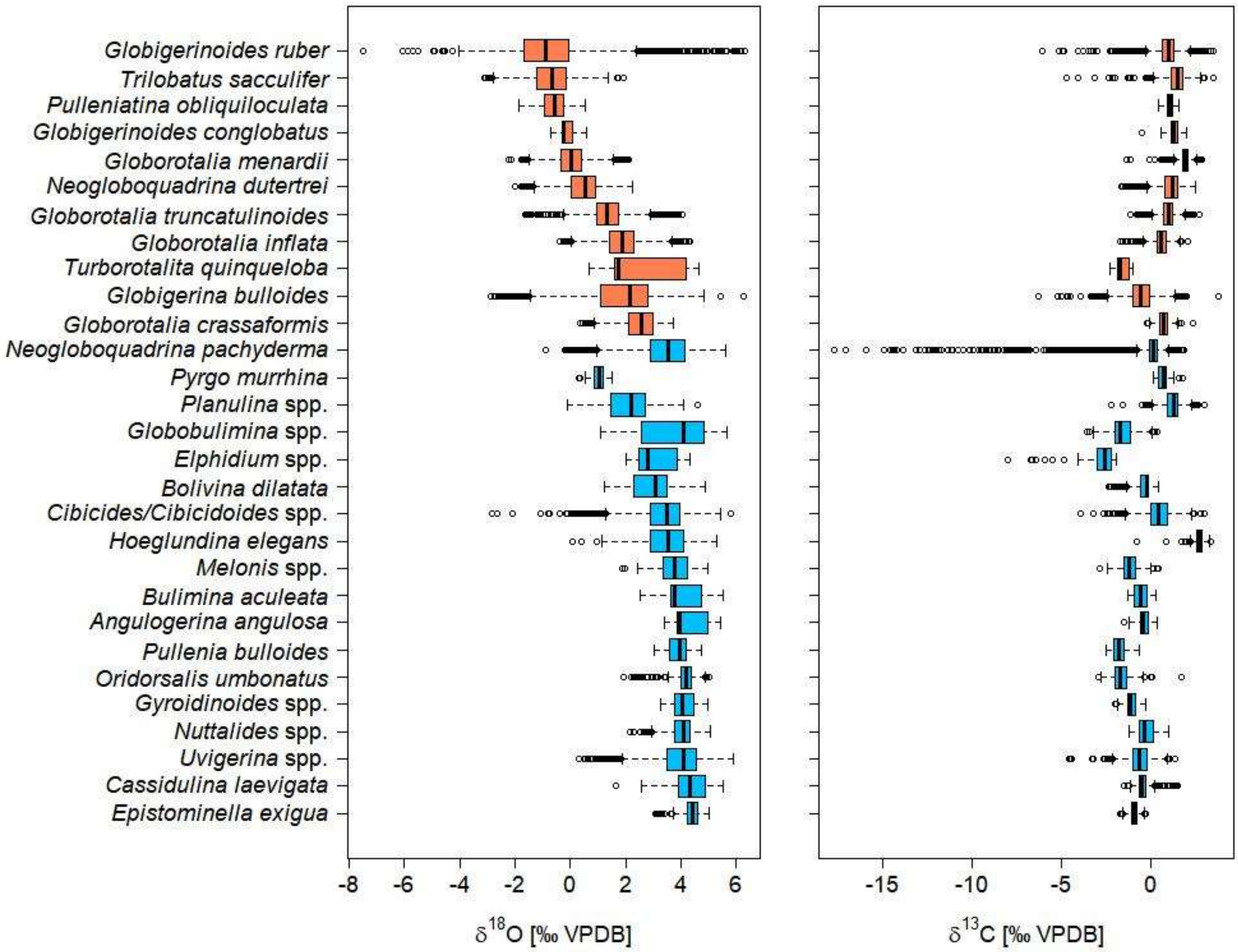

Figure 6: Box-whisker plot of oxygen (left) and carbon (right) stable isotope values of planktic (orange) and benthic (blue) Foraminifera at the species or genus level. The vertical line shows the median, left and right margins of the box indicate the 25th and 75th percentiles. The whiskers (the horizontal dashed lines) indicate the maximum/minimum values, or in case of outliers (open circles), highest/lowest data point that is less than 1.5 times above/below the interquartile range. The plot has been created with R's boxplot() function (R Core Team, 2017).

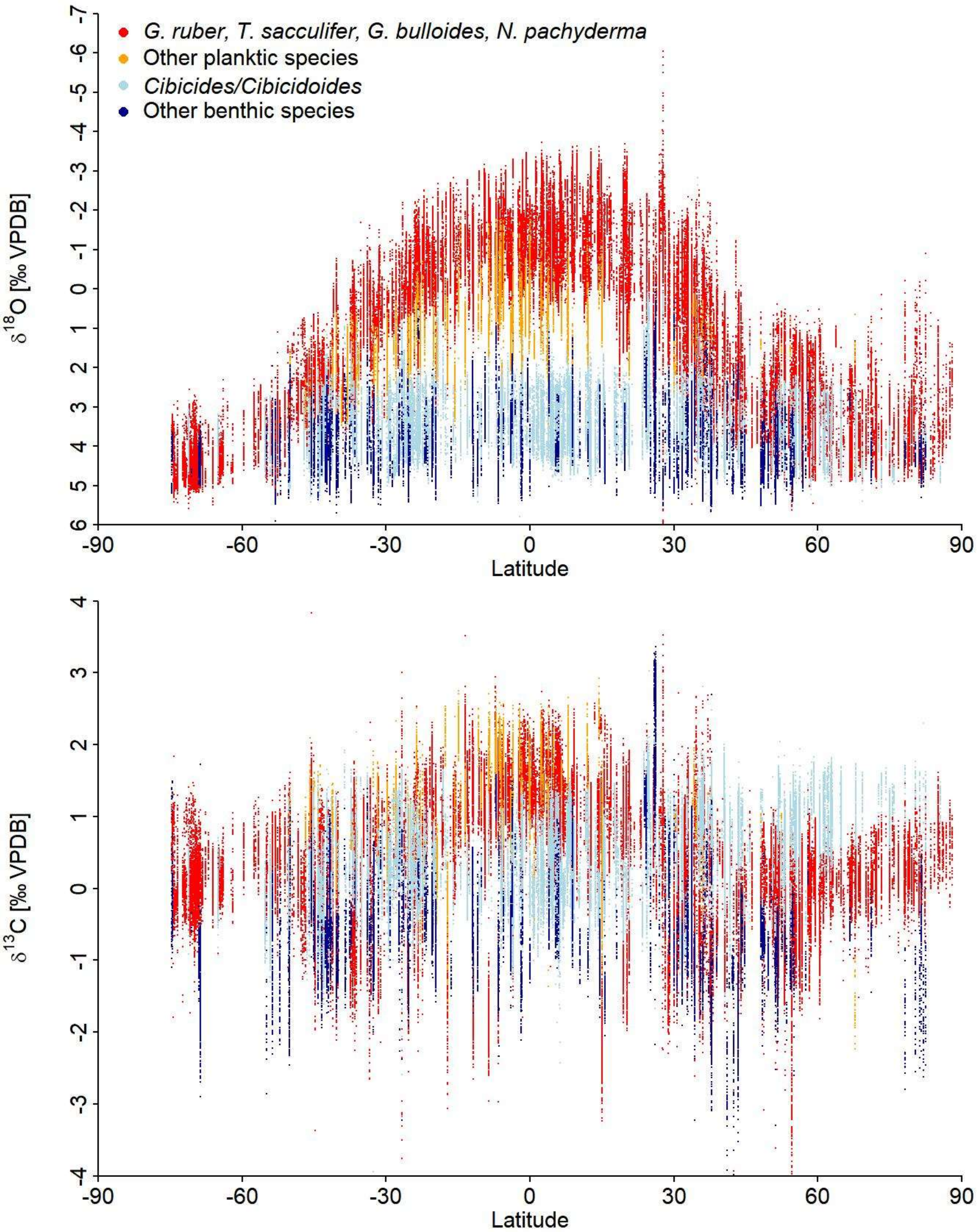

Figure 7: Distribution of $\delta^{18}O$ values (top) and $\delta^{13}C$ values (bottom) with latitude. Red/orange: planktic Foraminifera, blue: benthic Foraminifera. Extreme values outside the axis ranges are not shown.

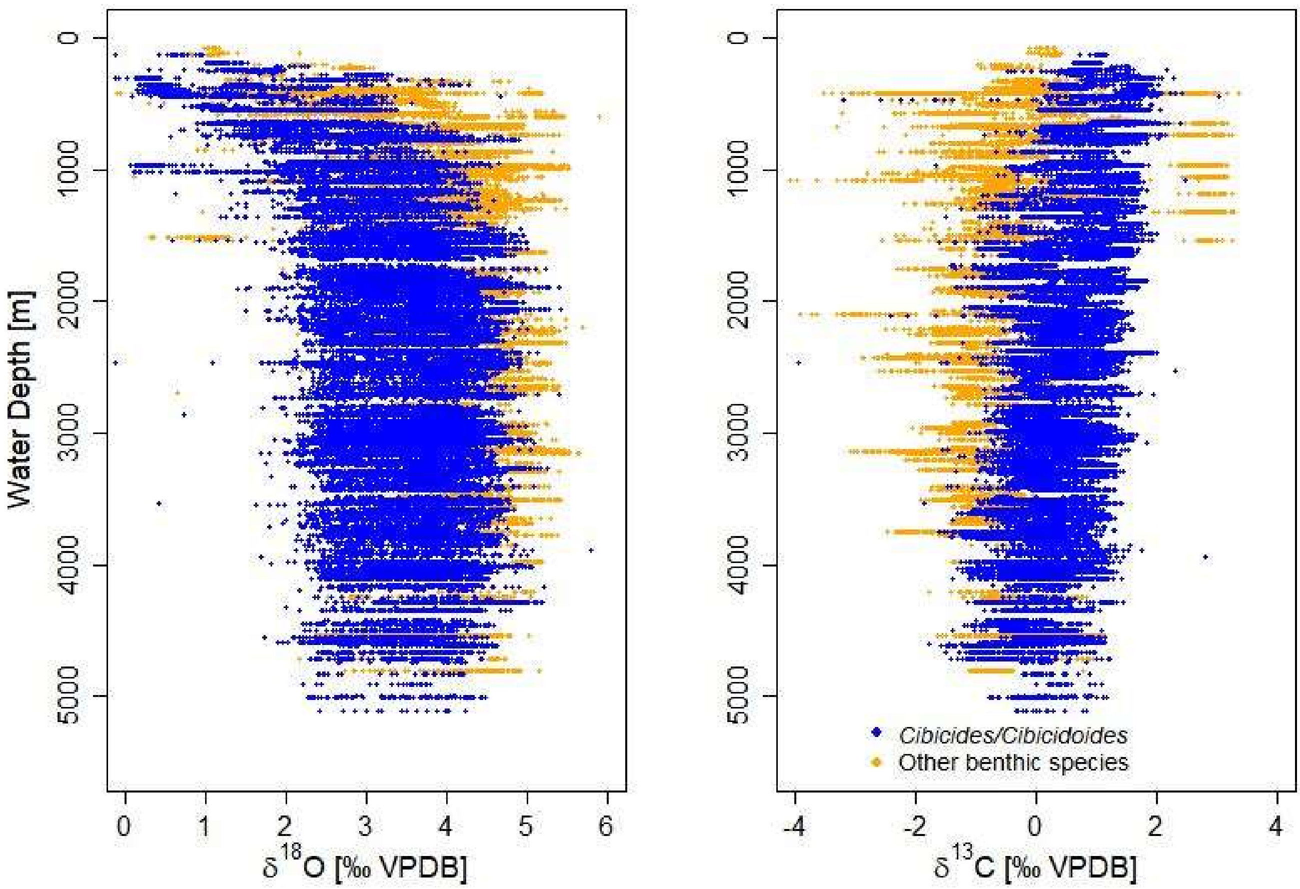

Figure 8: Distribution of benthic oxygen ($\delta^{18}O$, left) and carbon ($\delta^{13}C$, right) isotope values with water depth. Extreme values outside the axis ranges are not shown Blue: *Cibicides/Cibicidoides*, orange: other benthic species.

3.4. Distribution of radiocarbon ages

The data set contains 6,153 individual radiocarbon ages with a maximum age of about 56 ka. About 47% of the cores are associated with at least one radiocarbon date. Most of the radiocarbon-dated cores are from the Atlantic (44%) followed by the Pacific (28%) and the Arctic Ocean (12%) (Fig. 9). The temporal distribution of the radiocarbon ages (Fig. 10) shows that the last Deglaciation has been preferentially dated which is likely a consequence of the the scientific attention focussed on this time period and the limited stratigraphic extent of many coring techniques. The fraction of reversals is higher for the deglacial and glacial periods, where the the higher sampling density increases the likelihood of reversals.

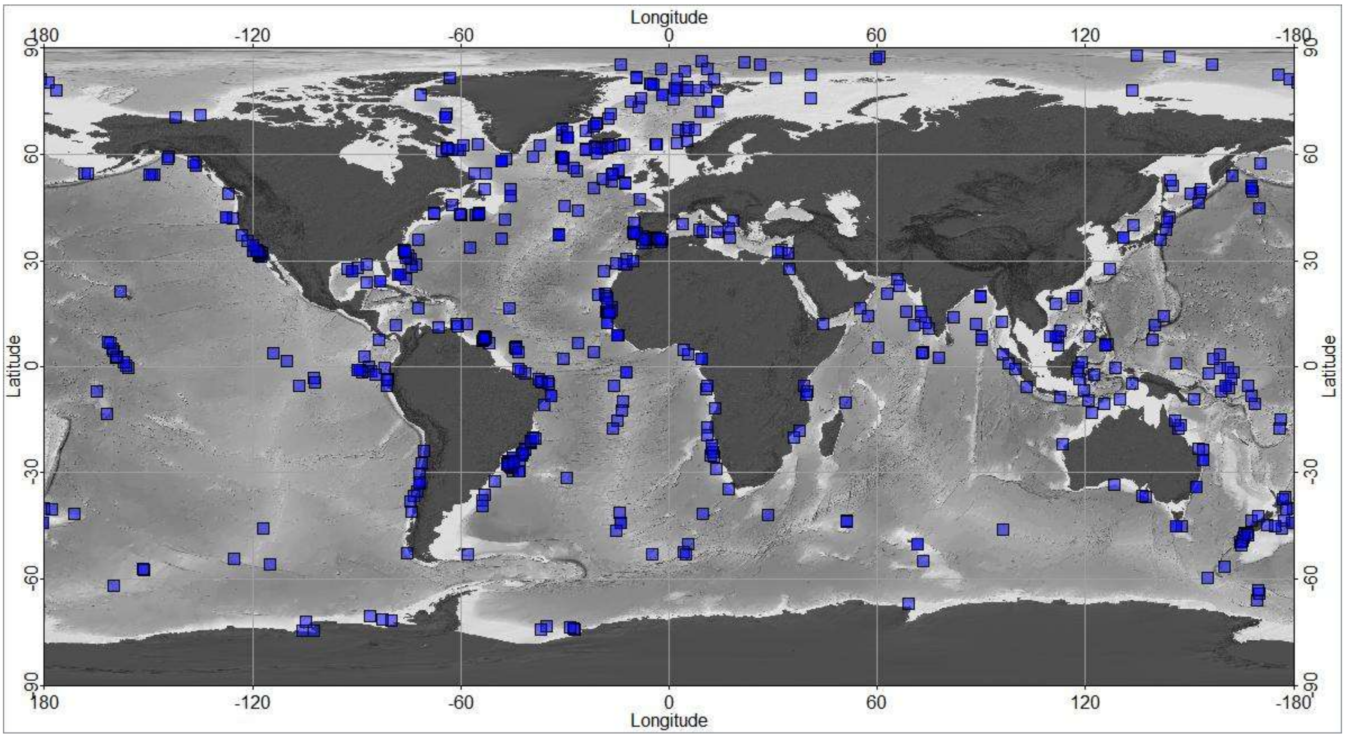

Figure 9: Spatial distribution of stable isotope records with at least one radiocarbon age. The map has been generated with PaleoDataView (Langner and Mulitza, 2019).

4. Possible applications

4.1 Marine Geology and Paleoceanography

Foraminiferal oxygen isotope ratios provide one of the most reliable tools for stratigraphy in marine sediments, particularly for time periods older than the range of the radiocarbon method, or if radiocarbon is not available or associated with large uncertainties due to unknown reservoir ages. Usually, oxygen-isotope stratigraphy is applied by using global (Imbrie et al., 1984; Prell et al., 1986; Lisiecki and Raymo, 2005) or basin-wide (Lisiecki and Stern, 2016) isotope reference curves. The collection presented here may provide the opportunity to find and align new records with the closest published isotope record measured on the same species, taking events into account that may only occur locally. Through its value for stratigraphy, our collection may also provide a foundation for the global mapping of seafloor sedimentation rates. The spatial quantitative mapping of sedimentation rates will allow the development of sediment budgets for the seafloor, including carbon burial.

Oxygen and carbon isotope ratios of Foraminifera are of great value for paleoclimatology by providing information on the history of seawater temperature and isotopic composition as well as circulation, productivity and carbon sequestration. This isotope atlas will allow for new global compilations to be undertaken to understand these processes at a global scale. Although distorted by habitat- and vital effects, there is hope that some of these effects can be represented and quantified in foraminiferal ecosystem/calcification models (e.g. Wolf-Gladrow et al., 1999; Schmidt and Mulitza, 2002; Fraile et al., 2008). Since the number of climate models containing the cycling of oxygen- and carbon isotopes is constantly growing (Marchal and Curry, 2008; Kurahashi-Nakamura et al., 2017; Tierney et al., 2020; Muglia et al., 2018; Völpel et al., 2017), foraminiferal isotopes may provide the opportunity to validate climate model experiments directly. Given this prospect and the spatial coverage, foraminiferal isotope data should be rescued, assembled and organized to secure the information for future applications as we continue to improve our understanding of the ecological and geochemical processes that determine isotope ratios in foraminiferal shells. Depending on the scientific problem, paleoceanographic compilations usually have specific criteria (e.g. temporal resolution or the availability of radiocarbon ages) for the selection of the records to be included (e.g., Jonkers et al., 2020). An atlas product that includes the majority of the available records enables quick selection of suitable data without an extensive literature review.

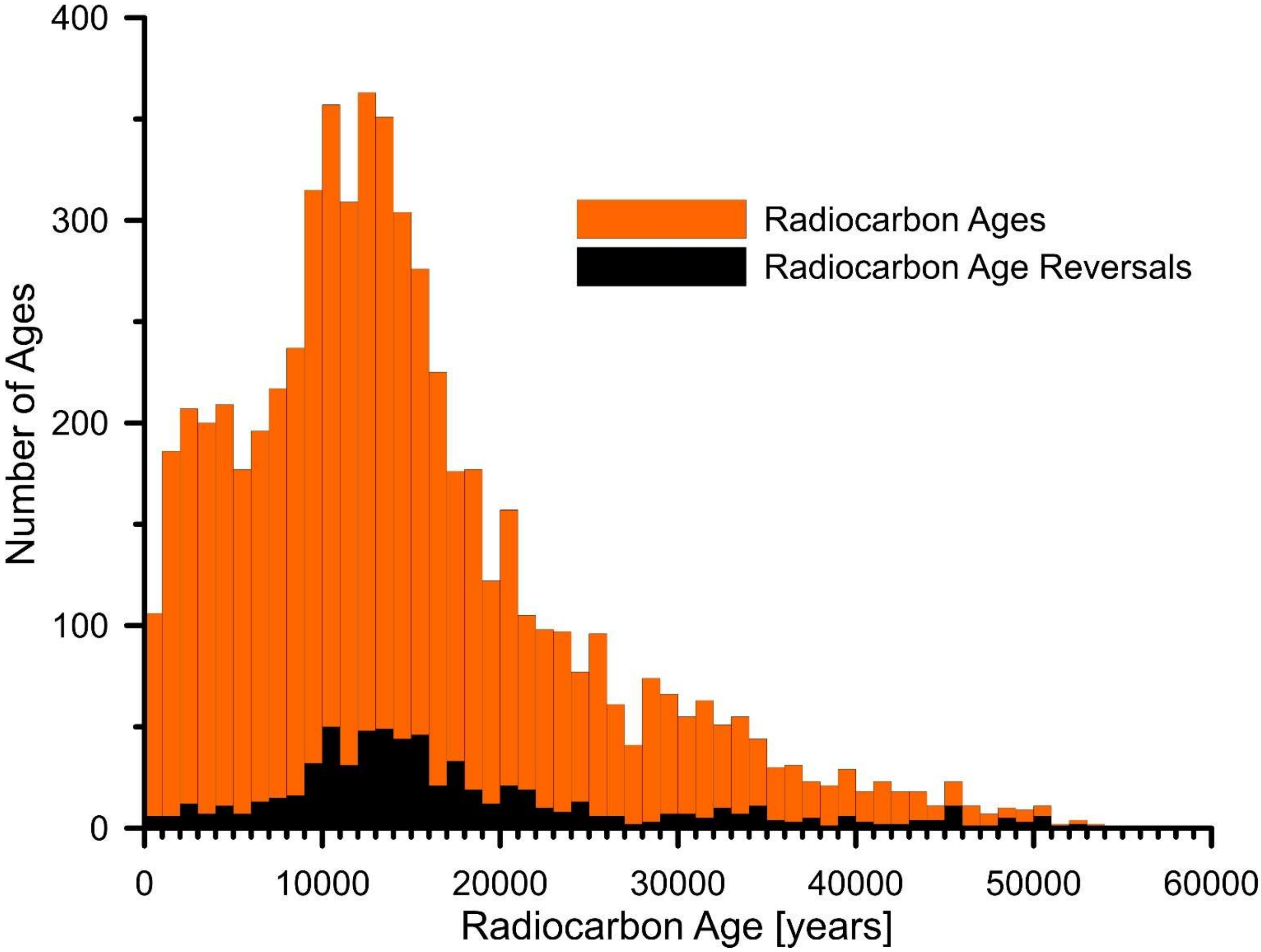

Figure 10: Distribution of radiocarbon ages in 1-kyr bins. Fraction of age reversals in black. Three negative radiocarbon ages are not included.

4.2 Expedition planning

The planning of marine coring campaigns requires prior knowledge of existing cores. Existing core locations are often resampled to get new sediment material or to extend the stratigraphic coverage with alternative coring gear that can penetrate deeper into the sediment. For example, many IODP and ODP cores are drilled at sites where short cores were previously retrieved. The knowledge of existing core locations and their stratigraphy allows identification of sampling gaps. Many aspects of marine expeditions are unpredictable, and schedules and coring plans regularly have to be adapted, often on a daily basis. The atlas we are presenting here provides fast access to stratigraphic data and may aid the identification of suitable alternative coring locations on ocean expeditions. Both the freely available PDV software and the atlas do not require web access and are therefore suitable to be used with a standard laptop computer.

4.3 Education

Foraminiferal oxygen isotope ratios are still the most valuable stratigraphic tool in marine sediments. The atlas covers various sedimentation regimes and therefore provides numerous examples of how factors like local hydrography, species or sedimentation rates influence the patterns of downcore isotope ratios. It therefore may be used as a resource to train students in regional isotope stratigraphy for studies in Paleoceanography, Paleoclimate and Marine Geology. Lecturers may employ the atlas together with PaleoDataView or with custom software to show examples on how isotope stages may be identified in different geological settings and on how isotope differences between species may be explained by hydrography and foraminiferal ecology. Students may also actively explore the patterns of isotope stratigraphies from different parts of the global seafloor to actively learn how global factors such as ice volume and local factors such as SST and freshwater input influence stable isotope records.

5 Data availability

All data included in the World Atlas of late Quaternary Foraminiferal Oxygen and Carbon Isotope Ratios can be downloaded at https://doi.org/10.1594/PANGAEA.936747~~https://doi.pangaea.de/10.1594/PANGAEA.936747~~. For use with the software PaleoDataView, the unzipped root directory (“WA_Foraminiferal_Isotopes_2022”) of the collection with all its content can be copied into the “Documents/PaleoDataView/” folder (Windows) or the /PaleoDataView/ folder under “Applications” (macOS). Select the root directory “WA_Foraminiferal_Isotopes_2022” under “Data -> Change Collection -> Change Working Directory” to explore the data. For use with custom software, netCDF files containing stable isotopes data are stored under “WA_Foraminiferal_Isotopes_2022\Foraminiferal Isotopes\Data\” and the radiocarbon data under “WA_Foraminiferal_Isotopes_2022\Age\”. Installers for current versions of PDV for both Windows 10 and macOS are available from https://www.marum.de/Stefan-Mulitza/PaleoDataView.html (last access: March 8, 2022).

6 Future: Building a dynamic World Atlas of Marine Sediments

The amount of proxy data from marine sediments is growing fast and the demand of data sets that can constrain past states of the Earth system is increasing. The complexity of the data makes it challenging to maintain and reduce the data sets into spatially and chronologically coherent and meaningful data sets. We propose to initiate an atlas series that provides raw data in a consistent data format as a first step from data archived in public databases (as published) towards more sophisticated data products describing past states of the ocean and the seafloor (Fig. 11). Eventually, these harmonized data sets can form a continuously growing and sustainable public “database layer” where proxy-specific raw data can be queried and directly loaded into software that provides the tools to generate homogenized data products that can reach out into other disciplines, i.e., climate modelling. We present a simple file-based data collection where each file contains only one proxy record rather than all available data of the core. Paleoclimatic data are often analysed and assembled in proxy-specific collections, because proxy-specific transfer functions have to be applied in order to quantify environmental variables. Furthermore, comparisons of records from different sites are preferably done on the same proxy type to ensure comparability. A single file per proxy facilitates the composition of proxy-specific collections, avoiding the additional costs (i.e., in terms of data management and disk space) of other downcore parameters in the same file. This modularity also allows individual scientists to separate their unpublished/unvalidated data from published/validated data that are ready to be included into a proxy collection. On the other hand, it is desirable to consistently apply the same stratigraphy to all proxies from a single core. PDV will automatically apply a single age model to all proxy records with the same core label. This requires that the depth scales and the core label of the different proxies are identical, when the data are imported.

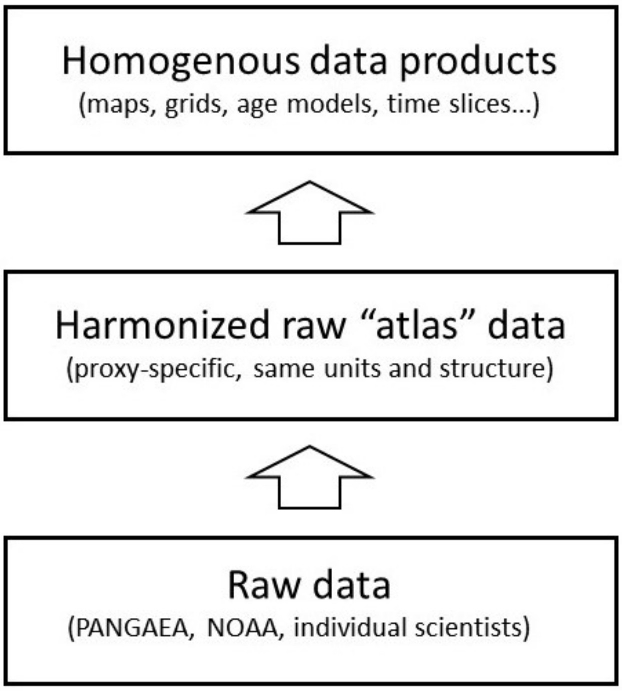

Figure 11: Potential workflow to form sustainable data products from raw databases.

Stable isotopes and radiocarbon ages usually provide the stratigraphic basis for further investigations. When collections of other proxies are added to PDV, these collections can rely on the stratigraphic data provided here and any changes in the stratigraphy will be applied to all proxy data in the collection. The efficient visualization of the data in PDV allows the identification of erroneous data and helps to improve the atlas product over time. The Excel export and import functions of PDV also ensure access to the data for individuals without strong programming skills.

As new foraminiferal isotope measurements become frequently available, we plan to update the atlas in reasonable intervals. Also, more historical isotope data may become available and need to be rescued (i.e. Borreggine et al., 2017). We hope this atlas will be a useful resource for the paleoceanography and marine geology community and will continue to grow through the contribution of new datasets as they are developed. Please contact the first author if you are interested to contribute to future updates of the atlas.

Appendix A

Table 1: References for the included stable isotope and radiocarbon data.

Core/Site	References
12PC51	Sikes and Keigwin, 1994
3MO67	Znaidi-Rivault, 2006a
64PE-174P13	Scussolini and Peeters, 2013
75KS23	Znaidi-Rivault, 2006b
75KS5	Znaidi-Rivault, 2006c
75KS50	Znaidi-Rivault, 2006d
75KS76	Znaidi-Rivault, 2006e
75KS79	Znaidi-Rivault, 2006f
A179-15	Mix et al., 1986; CLIMAP Project Members, 2004a
A7	Sun et al., 2005
AA_GC5	Rathburn et al., 1997
AAS9_21	Govil and Naidu, 2010
AHF-11343	Mortyn et al., 1996
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ALB226	Sarnthein et al., 1994
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BCCF10-09	Dias et al., 2018
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BS88-6-12	Horwege/Spielhagen, unpublished
BS88-6-13	Horwege/Spielhagen, unpublished
BS88-6-14	Horwege/Spielhagen, unpublished
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BS88-6-23	Horwege/Spielhagen, unpublished
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CH74-227	Labeyrie, 1996
CH75-03	Curry et al., 1988
CH75-04	Curry et al., 1988
CH84-27	Labeyrie, 1996
CHAT_16k	Yu et al., 2007
CHAT_1K	Weaver et al., 1998; McCave et al., 2008
CHAT10K	McCave et al., 2008; McCave et al., 2008; Maxson et al., 2019
CHAT3K	McCave et al., 2008
CHN115-70PC	Curry and Lohmann, 1982
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CHN115-89PC	Curry and Lohmann, 1982
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E27-23	Ferry et al., 2015; Anderson et al., 2009
E45-29	Howard and Prell, 1992
E49-17	Howard and Prell, 1992
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ELT25.011-CP	Waddell et al., 2009
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EW9209-3JPC	Curry et al., 1999
EW9302-24GGC	Oppo et al., 2015
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EW9504-02	Stott et al., 2000
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F2-92-P3	van Geen et al., 1996; Zheng et al., 2000
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Fan_17	Parker et al., 2016
FFC15	Keigwin and Lehman, 2015
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GeoB1028-5	Wefer et al., 1996; Bickert and Mackensen, 2004
GeoB1031-4	Wefer et al., 1996; Bickert and Mackensen, 2004
GeoB1032-2	Bickert and Mackensen, 2004
GeoB1032-3	Wefer et al., 1996; Bickert and Mackensen, 2004
GeoB1034-1	Bickert and Mackensen, 2004
GeoB1034-3	Bickert and Mackensen, 2004
GeoB1035-3	Bickert and Mackensen, 2004
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GeoB1041-3	Wolff, 1998; Bickert and Mackensen, 2004
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GeoB1113-4	Sarnthein et al., 1994
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GeoB15005-1	Martínez-Méndez et al., 2013
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GIK16856-2	Sarnthein et al., 1994; Schulz, 1995
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GIK17049-6	Jung, 1996
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H214	Sikes et al., 2016; Samson et al., 2005
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HU77-156	Andrews et al., 1991
HU84-008	Andrews et al., 1991

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HU85-027-016TWC	Hillaire-Marcel et al., 1989
HU87-033-009	Andrews and Tedesco, 1992
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HU-90-013-013P	Hillaire-Marcel et al., 1994
HU-90-013-017BC	Hillaire-Marcel et al., 1994
HU-91-045-052P	Hillaire-Marcel, unpublished
HU91-045-094	Hillaire-Marcel et al., 1994
HUD91_039-012P	Knudsen et al., 2008; Blake, JR et al., 1996
HYIV2015-B9	Li et al., 2018
IN68-5	Jorissen et al., 1993
INMD-097BX	Berger et al., 1985
INMD-101BX	Berger et al., 1985
INMD-104BX	Berger et al., 1985
INMD-109BX	Berger et al., 1985
INMD-110BX	Berger et al., 1985
INMD-111BX	Berger et al., 1985
INMD-113BX	Berger et al., 1985
INMD-115BX	Berger et al., 1985; Berger and Vincent, 1986
IOW226660-5	Mollenhauer et al., 2003; Mollenhauer, unpublished
IOW226920-3	Mollenhauer et al., 2003; Mollenhauer, unpublished
J-11	Gorbarenko and Southon, 2000
JM11-FI-19PC	Hoff et al., 2016
JM96-1225_1-GC	Hagen and Hald, 2002
JM96-1225_2-GC	Hagen and Hald, 2002
JR104-GC352	Hillenbrand et al., 2010
JR104-GC357	Hillenbrand et al., 2010
JR104-GC368	Hillenbrand et al., 2010
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JR104-GC372	Hillenbrand et al., 2010
JR179-TC493	Lu et al., 2016
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JR298-PC728	Channell et al., 2019
JR298-PC736	Channell et al., 2019
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KC82-26	Znaidi-Rivault, 1982; Caralp, 1988; Vergnaud-Grazzini and Pierre, 1991
KET82-21	Colin et al., 2021
KF-12	Costa et al., 2016a
KF14	Leonhardt et al., 2015
KF16	Repschläger et al., 2015
KH94-3_LM-8	Oba and Murayama, 2004
KN07304-0003PG	Curry et al., 1988
KN166-14-11JPC	Elmore et al., 2015a; Elmore et al., 2015b
KN166-14-3GGC	Elmore et al., 2015b
KN166-14-JPC-13	Hodell et al., 2010
KNR110-43PC	Curry and Crowley, 1987
KNR110-50	Curry et al., 1988
KNR110-55	Sarnthein et al., 1988
KNR110-58	Curry et al., 1988
KNR110-66	Curry et al., 1988
KNR110-71	Curry et al., 1988
KNR110-75	Curry et al., 1988
KNR110-82	Curry et al., 1988
KNR110-91	Curry et al., 1988
KNR140-01JPC	Keigwin, 2004
KNR140-02JPC	Keigwin, 2004
KNR140-02PG	Keigwin, 2004
KNR140-12JPC	Keigwin, 2004
KNR140-21GGC	Keigwin, 2004
KNR140-22JPC	Keigwin, 2004
KNR140-22PG	Keigwin, 2004
KNR140-28GGC	Keigwin, 2004
KNR140-29GGC	Keigwin, 2004

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KNR140-30GGC	Keigwin, 2004
KNR140-31GGC	Keigwin, 2004
KNR140-39GGC	Keigwin, 2004; Keigwin and Schlegel, 2002
KNR140-40GGC	Keigwin, 2004
KNR140-43GGC	Keigwin, 2004
KNR140-50GGC	Keigwin, 2004
KNR140-51GGC	Keigwin, 2004; Carlson et al., 2008; Rasmussen and Thomsen, 2012
KNR140-56GGC	Keigwin, 2004
KNR140-63JPC	Keigwin, 2004
KNR140-64GGC	Keigwin, 2004
KNR140-66GGC	Keigwin, 2004
KNR140-67JPC	Keigwin, 2004
KNR159-5-120GGC	Hoffman and Lund, 2012
KNR159-5-125GGC	Lund et al., 2015; Hoffman and Lund, 2012
KNR159-5-14GGC	Lund et al., 2015
KNR159-5-17JPC	Lund et al., 2015; Tessin and Lund, 2013
KNR159-5-20JPC	Lund et al., 2015
KNR159-5-22GGC	Lund et al., 2015; Hoffman and Lund, 2012
KNR159-5-30GGC	Lund et al., 2015; Tessin and Lund, 2013
KNR159-5-33GGC	Lund et al., 2015; Tessin and Lund, 2013
KNR159-5-36GGC	Lund et al., 2015; Carlson et al., 2008; Sortor and Lund, 2011; Came et al., 2003
KNR159-5-42JPC	Lund et al., 2015; Hoffman and Lund, 2012
KNR159-5-54GGC	Hoffman and Lund, 2012
KNR159-5-63GGC	Lund et al., 2015
KNR159-5-78GGC	Lund et al., 2015; Tessin and Lund, 2013
KNR159-5-90GGC	Lund et al., 2015
KNR166-2-105JPC	Lynch-Stieglitz et al., 2009
KNR166-2-106JPC	Lynch-Stieglitz et al., 2009
KNR166-2-113JPC	Lynch-Stieglitz et al., 2009
KNR166-2-119JPC	Lynch-Stieglitz et al., 2009
KNR166-2-127JPC	Lynch-Stieglitz et al., 2011

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KNR166-2-135JPC	Lynch-Stieglitz et al., 2009
KNR166-2-1GGC	Lynch-Stieglitz et al., 2009
KNR166-2-26JPC	Schmidt and Lynch-Stieglitz, 2011; Lynch-Stieglitz et al., 2011
KNR166-2-29JPC	Lynch-Stieglitz et al., 2011
KNR166-2-2JPC	Lynch-Stieglitz et al., 2009
KNR166-2-31JPC	Lynch-Stieglitz et al., 2011
KNR166-2-48JPC	Lynch-Stieglitz et al., 2009
KNR166-2-51JPC	Lynch-Stieglitz et al., 2009
KNR166-2-59JPC	Lynch-Stieglitz et al., 2009
KNR166-2-73GGC	Lynch-Stieglitz et al., 2011
KNR166-2-8GGC	Lynch-Stieglitz et al., 2009
KNR191-CDH19	Henry et al., 2016
KNR195-5-CDH23	Kalansky et al., 2015
KNR195-5-MC42C	Rustic et al., 2015
KNR197-10-17GGC	Keigwin and Swift, 2017
KNR197-3-23GGC	Oppo et al., 2018
KNR197-3-36GGC	Oppo et al., 2018
KNR197-3-45GGC	Oppo et al., 2018
KNR197-3-46CDH	Oppo et al., 2018
KNR197-3-47CDH	Oppo et al., 2018
KNR197-3-53GGC	Oppo et al., 2018
KNR197-3-60GGC	Oppo et al., 2018
KNR197-3-9GGC	Oppo et al., 2018.
KNR198-GGC-4	Keigwin, unpublished
KNR207-2_GGC3	Middleton et al., 2018
KNR207-2_GGC6	Middleton et al., 2018
KNR31-GPC5	Keigwin et al., 1991; Keigwin and Jones, 1994; Keigwin and Jones, 1995
KNR73_4PC	Keigwin and Lehman, 2015
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KS82-30	Vergnaud-Grazzini and Pierre, 1991; Caralp, 1988
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KT90-9_21	Oba and Murayama, 2004
KT90-9_5	Oba and Murayama, 2004
LaPAS-KF02	Pivel et al., 2013
LO09_21-2	Lackschewitz et al., 1998
LO09_23-2	Lackschewitz et al., 1998
LOUIS1610	Aharon, 2003
LOUIS1639	Aharon, 2003
LOUIS1640	Aharon, 2003
LOUIS1900	Aharon, 2003
LOUIS1924	Aharon, 2003
LOUIS1938	Aharon, 2003
LOUIS2023	Aharon, 2003
LV27-10-1	Kaiser, 2002
LV27-10-5	Kaiser, 2002
LV27-12-2	Kaiser, 2002
LV27-12-3	Kaiser, 2002
LV27-15-1	Kaiser, 2002
LV27-4-2	Kaiser, 2002
LV27-4-3	Kaiser, 2002
LV27-5-5	Kaiser, 2002
LV27-7-2	Kaiser, 2002
LV27-7-3	Kaiser, 2002
LV27-8-3	Kaiser, 2002
LV27-9-4	Kaiser, 2002
LV28-2-3	Kaiser, 2002
LV28-40-4	Kaiser, 2002
LV28-41-3	Kaiser, 2002
LV28-41-4	Kaiser, 2002
LV28-42-3	Kaiser, 2002
LV28-42-4	Kaiser, 2002
LV28-4-3	Kaiser, 2002

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LV28-44-2	Kaiser, 2002
LV28-44-3	Kaiser, 2002
M1_105KK	Sirocko, 1989
M1_114KK	Sirocko, 1989
M1_143KK	Sirocko, 1989
M1_162KK	Sirocko, 1989
M1_169SK	Sirocko, 1989
M1_181SK	Sirocko, 1989
M1_182SK	Sirocko, 1989
M1_223SK	Sirocko, 1989
M1_232SK	Sirocko, 1989
M125_469-3	Campos et al., 2020
M125-34-2	Bahr et al., 2020
M125-50-3	Campos et al., 2020
M125-55-7	Hou et al., 2020
M174_Kl11	Rohling et al., 2008
M25_4-KL11	Allen et al., 1999Emeis et al., 2000
M31_2-78_PC6	Geiselhart and Hemleben, 1998a
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M31_3_KL35	Müller and Budziak, 2004
M31_3_SL3011-1	Ivanova et al., 2003
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M35003-4	Hüls, 2000; Rühlemann et al., 1999; Mulitza et al., 1999; Hüls and Zahn, 2000; Vink et al., 2001 Mulitza and Rühlemann, unpublished
M35027-1	Stüber, 1999
M39008-3	Cacho et al., 2001; Löwemark et al., 2004
M40_4_SL67	Weldeab et al., 2003
M40_4_SL71	Weldeab et al., 2003
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M5_3a-420.2	Sirocko, 1989

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M74_4_1096-1	Paul et al., 2012
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M77_2_059-1	Nürnberg et al., 2015; Mollier-Vogel et al., 2013
M78_1_235-1	Reißig et al., 2019; Hoffmann et al., 2014; Poggemann et al., 2018
MC-29D	Keigwin et al., 2003
MD00-2361	Stuut et al., 2019; Spooner et al., 2011
MD01-2378	Holbourn et al., 2005; Dürkop et al., 2008
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MD01-2421	Oba and Murayama, 2004
MD01-2446	Marino et al., 2014
MD01-2461	Peck et al., 2008; Peck et al., 2007
MD02-2488	Govin et al., 2009
MD02-2489	Gebhardt et al., 2008
MD02-2496	Taylor et al., 2014; Cosma et al., 2008
MD02-2503	Hill et al., 2006; Grelaud et al., 2009; Sarnthein et al., 2015
MD02-2550	Williams et al., 2010; LoDico et al., 2006
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MD02-2594	Martínez-Méndez et al., 2010; Dyez et al., 2014
MD03-2607	Lopes dos Santos et al., 2013
MD03-2611G	Gingele et al., 2007; Moros et al., 2009; Deckker et al., 2012
MD03-2698	Lebreiro et al., 2009
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MD03-2707	Weldeab et al., 2016; Weldeab et al., 2007
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MD05-2896	Wang et al., 2016; Huang and Tian, 2012; Tian et al., 2010; Wan and Jian, 2014
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MD07-3128	Caniupán et al., 2011
MD08-3180	Repschläger et al., 2015; Schwab et al., 2012
MD09-3259	Govin, unpublished
MD10-3340	Dang et al., 2015
MD13-3455G	Fentimen et al., 2020
MD73-025	Duplessy, 1982; Labeyrie and Duplessy, 1985; Labracherie et al., 1989
MD76-123	Sirocko, 1989
MD76-125	Curry et al., 1988; Sirocko, 1989;
MD76-127	Sirocko, 1989
MD76-128	Sirocko, 1989
MD76-131	Duplessy, 1982; Sarnthein et al., 1988; Singh et al., 2011
MD76-132	Sirocko, 1989
MD76-135	Sarnthein et al., 1988
MD76-135	Sirocko, 1989
MD77-191	Sirocko, 1989
MD77-194	Sarnthein et al., 1988; Sirocko, 1989
MD77-200	Sarnthein et al., 1988
MD77-202	Sarnthein et al., 1988; Sirocko, 1989
MD77-203	Sarnthein et al., 1988
MD79-254	Curry et al., 1988
MD79-257	Duplessy et al., 1991; Levi et al., 2007
MD80-304	Labeyrie and Duplessy, 1985
MD81-BC15	Thunell, 2006b
MD81-LC03	Jenkins and Williams, 2004

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MD84-527	Pichon et al., 1992; Labracherie et al., 1989
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MD84-641	Fontugne and Calvert, 1992; Melki et al., 2010
MD88-769	Rosenthal et al., 1997
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MD88-784	Lynch-Stieglitz et al., 2016
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MD90-963	Bassinot et al., 1994
MD95-2002	Eynaud et al., 2012; Auffret et al., 2002; Zaragosi et al., 2006
MD95-2011	Dreger, 1999, Hevrey,, unpublished
MD95-2012	Dreger, 1999
MD95-2037	Labeyrie et al., 2005; Gherardi et al., 2009
MD95-2039	Schönfeld et al., 2003
MD95-2040	Voelker and Abreu, 2011; Abreu et al., 2003
MD95-2042	Shackleton et al., 2000; Hoogakker et al., 2015; Shackleton et al., 2004; Bard et al., 2004c, 2004b; Bard et al., 2004a
MD95-2043	Cacho et al., 2006
MD96-2048	Caley et al., 2018
MD96-2080	Rau et al., 2002
MD96-2084	Rau, 2003
MD96-2085	Chen et al., 2002
MD96-2098	Pichevin et al., 2005; Daniau et al., 2013
MD97-2106	Moy et al., 2006
MD97-2114	Cobianchi et al., 2012
MD97-2121	Carter and Manighetti, 2006
MD97-2138	Garidel-Thoron et al., 2007
MD97-2142	Chen et al., 2003; Ren et al., 2017
MD97-2151	Wei et al., 2006; Lee et al., 1999
MD98-2170	Stott et al., 2007
MD98-2176	Stott et al., 2007

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MD99-2227	Evans et al., 2007
MD99-2227P	Evans et al., 2007
MD99-2236	Jennings et al., 2015
MD99-2254	Vernal and Hillaire-Marcel, 2006
MD99-2263	Andrews et al., 2009
MD99-2339	Voelker et al., 2006
MD99-2343	Frigola et al., 2008
ME0005-24JC	Kienast et al., 2013; Kusch et al., 2010; Kienast et al., 2007; Dubois et al., 2011
ME0005A-43JC	Benway et al., 2006
MG237	Giresse et al., 1982; Sarnthein et al., 1994
ML1208-06BB	Lynch-Stieglitz et al., 2015
ML1208-10GC	Lynch-Stieglitz et al., 2015
ML1208-11GC	Lynch-Stieglitz et al., 2015
ML1208-12GC	Lynch-Stieglitz et al., 2015
ML1208-13BB	Monteagudo et al., 2021; Lynch-Stieglitz et al., 2015; Costa and McManus, 2017
ML1208-15GC	Lynch-Stieglitz et al., 2015
ML1208-17PC	Lynch-Stieglitz et al., 2015
ML1208-17TC	Lynch-Stieglitz et al., 2015
ML1208-18GC	Lynch-Stieglitz et al., 2015; Monteagudo et al., 2021; Lynch-Stieglitz, unpublished
ML1208-19GC	Lynch-Stieglitz et al., 2015
ML1208-20BB	Monteagudo et al., 2021; Lynch-Stieglitz et al., 2015; Costa and McManus, 2017
ML1208-27BB	Lynch-Stieglitz et al., 2015; Monteagudo et al., 2021; Lynch-Stieglitz, unpublished
ML1208-28BB	Lynch-Stieglitz et al., 2015; Costa et al., 2016b; Costa and McManus, 2017; Monteagudo et al., 2021; Lynch-Stieglitz, unpublished
ML1208-30BB	Lynch-Stieglitz et al., 2015
ML1208-31BB	Lynch-Stieglitz et al., 2015; Jacobel et al., 2016; Monteagudo et al., 2021; Lynch-Stieglitz, unpublished
ML1208-32BB	Monteagudo et al., 2021; Costa and McManus, 2017
ML1208-34BB	Lynch-Stieglitz et al., 2015
ML1208-35BB	Lynch-Stieglitz et al., 2015

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ML1208-36BB	Costa et al., 2016b; Costa and McManus, 2017; Monteagudo et al., 2021; Lynch-Stieglitz, unpublished
ML1208-37BB	Lynch-Stieglitz et al., 2015; Jacobel et al., 2016; Monteagudo et al., 2021
MR00-K03-PC-01	Harada et al., 2004
MR00-K03-PC-04	Harada et al., 2004
MS21PC	Hennekam et al., 2015
MSM05_5_723-2	Werner et al., 2016
MV0502-4JC	Waddell et al., 2009
MW9109-15GGC	Patrick and Thunell, 1997; Yu et al., 2010
MW9109-36BC	Broecker et al., 2001; Lynch-Stieglitz, unpublished
MW9109-44GGC	Broecker et al., 2001; Lynch-Stieglitz, unpublished
MW9109-48GGC	Yu et al., 2010; Lynch-Stieglitz, unpublished
MW9109-51BC	Lynch-Stieglitz, unpublished
MW9109-55GGC	Fehrenbacher and Martin, 2011; Lynch-Stieglitz, unpublished
NA87-22	Vidal et al., 1997; Waelbroeck et al., 2001; Waelbroeck et al., 2006
NBP9802_3GC1	Chase et al., 2003
NBP9802_4GC1	Chase et al., 2003
NBP9802_5GC1	Chase et al., 2003
NEAP-04K	Rickaby and Elderfield, 2005; Hall et al., 2004
OC205-103GGC	Curry et al., 1999
OC205-2-100GGC	Slowey and Curry, 1995; Came et al., 2008
OC205-2-103GGC	Slowey and Curry, 1995; Curry et al., 1999; Came et al., 2003
OC205-2-106GGC	Slowey and Curry, 1995
OC205-2-108GGC	Slowey and Curry, 1995
OC205-2-117JPC	Slowey and Curry, 1995
OC205-2-149JPC	Slowey and Curry, 1995
OC205-2-33GGC	Slowey and Curry, 1995
OC205-2-7JPC	Slowey and Curry, 1995
OC205-2-97JPC	Slowey and Curry, 1995
OCE326-26GGC	Keigwin et al., 2005
OCE326-MC25B	Keigwin et al., 2005
OCE3326-14GGC	Keigwin et al., 2005

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ODP1063	Channell et al., 2012
ODP1078C	Rühlemann et al., 2004; Kim et al., 2003; Mulitza, unpublished
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ODP1084B	Lynch-Stieglitz et al., 2006
ODP1119	Carter et al., 2004
ODP1120	Duncan et al., 2016
ODP1123	Elderfield et al., 2012
ODP1125	Peterson et al., 2020
ODP1127	Andres, 2002
ODP1168	Nürnberg et al., 2004
ODP1170	Nürnberg et al., 2004
ODP1172A	Nürnberg et al., 2004; Nürnberg and Groeneveld, 2006
ODP658C	Knaack and Sarnthein, 2005; Knaack, 1997; deMenocal et al., 2000
ODP769	Linsley, 1996
ODP817A	Haddad et al., 1993
ODP818B	Haddad et al., 1993
ODP819A	Alexander et al., 1993
ODP820A	Peerdeman et al., 1993
ODP980	Oppo et al., 2003
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OK92_2182	Kaiser, 2002
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Orgon4-KS8	Sirocko, 1989; Sirocko et al., 2000
P1-003MC	Sejrup et al., 2010
P69	Weaver et al., 1998; Nelson et al., 2000
P71	Duncan et al., 2016
PAR87A-01	Zahn et al., 1991
PAR87A-02	Zahn et al., 1991

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PASSAP_PS009PC	Hennekam et al., 2015
PC17	Lee et al., 2001
PC20	Lee et al., 2001
PC75-1	Shao et al., 2019
PC75-2	Shao et al., 2019
PC83-1	Shao et al., 2019
PLDS-7G	Keigwin and Lehman, 2015
POS200_10_6-2	Abrantes et al., 2018; Abrantes et al., 2001; Abrantes et al., 1998; Baas et al., 1997; Mienert et al., 1998
POS457-905-2	Mirzaloo et al., 2019
POS457-909-2	Mirzaloo et al., 2019
PS1006-1	Grobe and Mackensen, 1992
PS1021-1	Grobe, 1986a
PS1023-1	Grobe, 1986b
PS1224-1	Grobe, 1986b
PS1243-1	Bauch, 2001
PS1290-4	Hebbeln, 1992; Elverhøi et al., 1995
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PS1295-4	Jones and Keigwin, 1988
PS1308-3	Spielhagen, unpublished
PS1367-2	Grobe and Mackensen, 1992
PS1368-3	Grobe, 1996a
PS1369-2	Grobe, 1996b
PS1370-2	Grobe, 1996c
PS1375-3	Grobe, 1996d
PS1378-3	Grobe, 1996e
PS1379-3	Grobe, 1996f
PS1380-3	Grobe and Mackensen, 1992
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PS1420-1	Melles, 1991
PS1420-2	Melles, 1991
PS1431-1	Grobe and Mackensen, 1992
PS1436-1	Ott and Gersonde, 1997a
PS1451-1	Cordes and Fütterer, 1997a
PS1458-1	Winn, 2014d
PS1458-2	Winn, 2014e
PS1461-1	Grobe, 1996j
PS1467-1	Cordes and Fütterer, 1997b
PS1479-2	Grobe and Mackensen, 1992
PS1481-3	Grobe and Fütterer, 1990
PS1494-2	Melles, 1991
PS1494-3	Melles, 1991
PS1498-1	Melles, 1991
PS1498-2	Melles, 1991
PS1506-1	Mackensen et al., 1994
PS1519-12	Horwege/Spielhagen, unpublished
PS1524-1	Köhler, 1991
PS1527-10	Köhler, 1991
PS1535-5	Spielhagen et al., 2004; Nørgaard-Pedersen et al., 2003
PS1535-8	Spielhagen et al., 2004; Nowaczyk et al., 2003
PS1563-2	Grobe, 2002a
PS1564-2	Grobe, 2002b
PS1565-2	Hillenbrand, 1995
PS1576-2	Brehme, 1992
PS1577-1	Brehme, 1992
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PS1611-3	Melles, 1991
PS1612-1	Melles, 1991
PS1612-2	Melles, 1991
PS1613-2	Melles, 1991
PS1613-4	Melles, 1991
PS1640-1	Grobe and Mackensen, 1992
PS1648-1	Grobe and Mackensen, 1992
PS1649-2	Ott and Gersonde, 1997b
PS1650-1	Ott and Gersonde, 1997c
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PS1652-2	Ott and Gersonde, 1997h
PS1653-1	Ott and Gersonde, 1997i
PS1653-2	Ott and Gersonde, 1997j
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PS1654-2	Ott and Gersonde, 1997l; Bianchi and Gersonde, 2004
PS1704-4	Horwege/Spielhagen, unpublished
PS1706-1	Horwege/Spielhagen, unpublished
PS1707-1	Horwege/Spielhagen, unpublished
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PS1730-2	Nam, 1997; Stein et al., 1996
PS1754-1	Niebler, 1995
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PS1813-6	Grobe, 1996p
PS1816-1	Grobe, 1996q
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PS2076-3	Niebler, 1995
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PS2177-1	Nørgaard-Pedersen et al., 2003; Nørgaard-Pedersen et al., 1998
PS2185-3	Spielhagen et al., 2004; Nørgaard-Pedersen et al., 1998
PS2195-4	Nørgaard-Pedersen et al., 1998
PS2200-2	Nørgaard-Pedersen et al., 1998
PS2206-4	Stein et al., 1994
PS2208-1	Stein et al., 1994; Stein and Schneider, 2003
PS2212-3	Wollenburg et al., 2001
PS2250-5	Niebler, 1995
PS2423-4	Notholt, 1998
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PS2487-6	Flores et al., 1999
PS2495-3	Mackensen et al., 2001; Gersonde et al., 2003; Niebler, 2004a; Niebler, 2004b; Niebler, 2004c
PS2498-1	Mackensen et al., 2001; Gersonde et al., 2003; Niebler, 2004d; Niebler, 2004e; Niebler, 2004f
PS2499-5	Mackensen et al., 2001; Gersonde et al., 2003
PS2539-2	Hillenbrand et al., 2003
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PS2647-2	Voelker, 1999
PS2709-1	Flores et al., 2000
PS2819-2	Vernaleken, 1999
PS2820-1	Vernaleken, 1999
PS2837-5	Nørgaard-Pedersen et al., 2003
PS2876-1	Nørgaard-Pedersen et al., 2003
PS2876-2	Nørgaard-Pedersen et al., 2003
PS2887-1	Nørgaard-Pedersen and Spielhagen, 2000; Nørgaard-Pedersen et al., 2003
PS2887-2	Nørgaard-Pedersen, 2000b; Nørgaard-Pedersen et al., 2003
PS51_038-3	Nørgaard-Pedersen, 2006
PS51_038-4	Spielhagen et al., 2004
PS66_309-1	Winkelmann et al., 2008
PS69_251-1	Hillenbrand et al., 2017; Smith et al., 2014
PS69_912-3	Ronge, 2019b, 2019a
PS69_912-4	Ronge, 2019b, 2019a
PS72_396-3	Geibert et al., 2021
PS75_056-1	Ullermann et al., 2016
PS75_072-4	Benz et al., 2016; Tiedemann and Lembke-Jene, unpublished
PS75_073-2	Benz et al., 2016; Tiedemann and Lembke-Jene, unpublished
PS75_085-1	Benz et al., 2016; Tiedemann and Lembke-Jene, unpublished
PS75_160-1	Hillenbrand et al., 2017
PS75_167-1	Hillenbrand et al., 2017
PS75-059-2	Ullermann et al., 2016; Ronge et al., 2016
Q208	Winn, 2013a
Q585	Weaver et al., 1998
Q859	Winn and Fenner, 2013a
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R657	Weaver et al., 1998
RAMA44P	Keigwin, 1987
RAPiD-10-1P	Thornalley et al., 2011; Thornalley et al., 2010
RAPiD-12-1K	Thornalley et al., 2010, 2009
RAPiD-15-4P	Thornalley et al., 2010
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RC09-150	Bé and Duplessy, 1976
RC09-166	Tierney et al., 2017
RC10-131	Anderson et al., 1989
RC10-289	Matsumoto and Lynch-Stieglitz, 2003
RC11-120	Curry et al., 1988
RC11-238	Koutavas and Lynch-Stieglitz, 2003
RC11-83	Charles et al., 1996; Charles and Fairbanks, 1992; Piotrowski et al., 2004
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RC16-59	Lynch-Stieglitz, unpublished
RC16-84	Oppo and Horowitz, 2000
RC16-86	Oppo and Horowitz, 2000
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RC8-102	Koutavas and Lynch-Stieglitz, 2003
RC9-150	Wells et al., 1994
RC9-203	Oppo and Fairbanks, 1987
RECORD23	Colin et al., 2021
RNDB-11PC	Keigwin and Lehman, 2015
RNDB-13PC	Keigwin and Lehman, 2015
RR0503_125JPC	Schiraldi et al., 2014; Sikes et al., 2016
RR0503_41JPC	Sikes et al., 2016
RR0503-79JPC	Sikes et al., 2016
RR0503_83JPC	Sikes et al., 2016
RR0503_83TC	Sikes et al., 2016
RR0503-87JPC	Sikes et al., 2016
RR0503_87TC	Sikes et al., 2016
RR0503-64JPC	Schiraldi et al., 2014; Sikes et al., 2016
RR0503-79JPC	Schiraldi et al., 2014
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RS105_GC23	Troedson and Davies, 2001
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RS112GC10	Troedson and Davies, 2001
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RS147-GC07	Sikes et al., 2016; Sikes et al., 2009
RS67-GC13	Lynch-Stieglitz et al., 1994
RS67-GC16	Lynch-Stieglitz et al., 1994
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S794	Weaver et al., 1998
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SAT-048A	Frozza et al., 2020
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SCS90-36	Huang et al., 1997
SHAK06-5K	Ausín et al., 2019
SK129-CR05	Guptha et al., 2005
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SK157-GC04	Saraswat et al., 2005
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SK218_1	Govil and Divakar Naidu, 2011; Govil, Naidu, Mulitza, unpublished
SK237-GC04	Saraswat et al., 2013
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SL-1	Guptha et al., 2005
SL-4	Guptha et al., 2005
SN6	Tiwari et al., 2015
SO12_98	Winn, 2012
SO126_39KL	Weldeab et al., 2019
SO130_261KL	Rad et al., 2003
SO135_03GKG	Winn, 2014a
SO135_04SL	Winn, 2014b
SO135_05GKG	Winn, 2014c
SO135_21GKG	Winn, 2014f
SO135_40KL	Winn, 2014f
SO136_003GC	Ronge et al., 2015; Barrows et al., 2007
SO136-111	Crosta et al., 2004; Sturm, 2003
SO161_5_50SL	Blumberg et al., 2008
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SO189-39KL	Mohtadi et al., 2014; Mohtadi, unpublished
SO201-2-12KL	Riethdorf et al., 2013
SO201-2-85	Riethdorf et al., 2013; Max et al., 2014
SO202_1_27-6	Maier et al., 2015; Maier et al., 2018
SO213_2_60-1	Molina-Kescher et al., 2016
SO213_2_82-1	Ronge et al., 2015
SO213_2_84-1	Ronge et al., 2015
SO213-59-2	Tapia et al., 2015; Molina-Kescher et al., 2016; Nürnberg, unpublished
SO225-08-3	Raddatz et al., 2017; Nürnberg, unpublished
SO225-53-3	Raddatz et al., 2017; Nürnberg, unpublished
SO236_52-4	Bunzel et al., 2017
SO26_127KA	Winn et al., 1991
SO26_131KA	Winn et al., 1991
SO26_141KA	Sarnthein and Winn, 2013b
SO26_189KA	Sarnthein and Winn, 1991
SO26_222KA	Sarnthein and Winn, 2013a
SO26_58KA	Winn et al., 1991
SO26_90KA	Winn et al., 1991
SO28-05KL	Sirocko, 1989
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SO28-18KL	Sirocko, 1989
SO35_2_101KL	Winn et al., 1990
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SO35_3_182KL	Winn et al., 1990
SO35_3_211KL	Winn et al., 1990
SO35_3_272KL	Winn, 2013i
SO36_2_17SL	Lynch-Stieglitz et al., 1994
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SO42-15KL	Sirocko, 1989

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SO42-57KL	Sirocko, 1989
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SO42-82KL	Sirocko, 1989
SO42-87KL	Sirocko, 1989
SO75_3_26KL	Zahn et al., 1997
SO82_2-2	Lackschewitz et al., 1998
SO82_4-2	Lackschewitz et al., 1998; Moros et al., 1997
SO82_5-2	Jung, 1996; Lackschewitz et al., 1998; van Kreveld et al., 2000
SO82_7-2	Lackschewitz et al., 1998.
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SO93_1_22KL	Weber, 1997
Station-8s-MC	Harada et al., 2004
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SU81-07	Kallel et al., 1997
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TAN0803-09	Maxson et al., 2019; Bostock et al., 2015
TAN0803-27	Maxson et al., 2019
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TGS-931	Schröder et al., 2018
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TTN057-13-PC4	Kanfoush et al., 2002; Kanfoush et al., 2000; Shemesh et al., 2002
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U306	Winn, 2016
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UM94PC31	Corselli et al., 2002
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V22-108	Charles et al., 1991
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VNTR01_10PC	Keigwin and Lehman, 2015
W8402A-14	Jasper et al., 1994
W8709A-1	Lyle et al., 1992
W8709A-13	Lyle et al., 1992; Lund and Mix, 1998
W8709A-8	Lyle et al., 1992; Ortiz et al., 1997
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WIND-28K	Kiefer et al., 2006; Johnstone et al., 2014
Y71-06-12	Shackleton, 1977a
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