The SISAL database: a global resource to document oxygen and carbon isotope records from speleothems

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Abstract. Stable isotope records from speleothems provide information on past climate changes, most particularly information that can be used to reconstruct past changes in precipitation and atmospheric circulation. These records are increasingly being used to provide “out-of-sample” evaluations of isotope-enabled climate models. SISAL (Speleothem Isotope Synthesis and Analysis) is an international working group of the Past Global Changes (PAGES) project. The working group aims to provide a comprehensive compilation of speleothem isotope records for climate reconstruction and model evaluation. The SISAL database contains data for individual speleothems, grouped by cave system. Stable isotopes of oxygen and carbon ($\delta^{18}O, \delta^{13}C$) measurements are referenced by distance from the top or bottom of the speleothem. Additional tables provide information on dating, including information on the dates used to construct the original age model and sufficient information to assess the quality of each data set and to erect a standardized chronology across different speleothems. The metadata table provides location information, information on the full range of measurements carried out on each speleothem and information on the cave system that is relevant to the interpretation of the records, as well as citations for both publications and archived data. The compiled data are available at https://doi.org/10.17864/1947.147.

1 Introduction

Speleothems are inorganic carbonate deposits (mostly calcite and aragonite) that grow in caves and form from drip water supersaturated with respect to CaCO$_3$. Speleothems are highly suitable for radiometric dating using uranium-series disequilibrium techniques. Since they form through continuous accretion, speleothems can provide a highly resolved record of environmental conditions, generally with a temporal resolution ranging from seasonal scale to 100 years, depending on sampling resolution.

Speleothem records are one of the types of record widely used to reconstruct past climate changes (see Bradley, 2015 for an overview of other methods). Speleothem growth is, in itself, an indicator of precipitation availability (Ayliffe et al., 1998; Wang et al., 2004), and variations in annual growth increments have been interpreted as an index of precipitation amount (Fleitmann et al., 2004; Polyak and Asmerom, 2001; Trouet et al., 2009). Many different types of measurements have been made on speleothems, but the most common are the stable isotopes of oxygen and carbon ($\delta^{18}O, \delta^{13}C$). Although the interpretation of such records can be complicated, for samples that are deposited close to equilibrium, changes in $\delta^{18}O$ are primarily a signal of changes in precipitation amount and source, precipitation temperature, and cave temperature (Affek et al., 2014; Hu et al., 2008; McDermott, 2004; Wang et al., 2008) and have been widely used to reconstruct changing atmospheric circulation patterns (e.g. Bar-Matthews et al., 1999; Cai et al., 2012, 2015; Luetscher et al., 2015; Spöt and Mangini, 2002; Trouet et al., 2009). Changes in $\delta^{13}C$ are a more indirect signal of precipitation changes. If not affected by non-equilibrium deposition (Baker et al., 1997), $\delta^{13}C$ can reflect the changing abundance of C$_3$ and C$_4$ plants above the cave (Baldini et al., 2008; Dorale et al., 1998) or the availability of soil CO$_2$ during the dissolution of limestone (Genty et al., 2003; Hendy, 1971; Salomons and Mook, 1986). Speleothem records are widely distributed geographically, and this makes them an ideal type of archive for regional climate reconstructions.

An increasing number of climate models explicitly simulate water isotopes as a tool for characterizing and diagnosing the atmospheric hydrological cycle (Schmidt et al., 2007; Steen-Larsen et al., 2017; Sturm et al., 2010; Werner et al., 2011; Haese et al., 2013). Such models are evaluated against modern observations of the isotopic composition of rainwater (see for example Yoshimura et al., 2008; Steen-Larsen et al., 2017). However, evaluations against palaeo-records such as the $\delta^{18}O$ records from speleothems can be used to provide an “out-of-sample” test (Schmidt et al., 2014) of these models. Thus, in addition to their use for climate reconstruction, speleothem records are a useful addition to the tools that are used for climate-model evaluation.

More than 500 speleothem data sets have been published to date, 70 % of which have been published in the decade since 2007. There have been some attempts to provide syntheses of speleothem data, particularly in the context of providing climate reconstructions or data sets for model evaluation (e.g. Bolliet et al., 2016; Caley et al., 2014; Harrison et al., 2014; Shah et al., 2013). However, these compilations generally lack sufficient information to allow careful screening of the records to ensure the reliability of the climate interpretation or the quality of the dating of the record. Furthermore, none of them provide comprehensive coverage of the globe.

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Table 1. Information on speleothem records (entities) in the SISAL_v1 database. Elevation (Elv) is given in metres above sea level and latitude (Lat) and longitude (Long) in decimal degrees. For convenience, we have given the location of each record, although this information is not available in the database itself. Note that the latitude and longitude of Abaliget, Brown’s cave and Uamh an Tartair are given correctly here but are incorrect in the SISAL_v1 database.

| Entity name | Site name | Elv (m) | Lat (°) | Long (°) | Region | Citations |
|-------------|-----------|---------|---------|----------|--------|-----------|
| AB-DC-01, AB-DC-03, AB-DC-12 | Abaco Island cave | −45 | 26.2300 | −77.1600 | Bahamas | Arienzo et al. (2017) |
| AB-DC-09 | Abaco Island cave | −45 | 26.2300 | −77.1600 | Bahamas | Arienzo et al. (2015, 2017) |
| ABA_1, ABA_2 | Abaliget cave | 209 | 46.1333 | 18.1666 | Hungary | Koltai et al. (2017) |
| Abissal, Ale-1 | Abissal cave | 100 | −5.6000 | −37.7330 | Brazil | Cruz et al. (2009) |
| Ach-1 | Achere cave | 1534 | 8.6036 | 40.3729 | Ethiopia | Asrat et al. (2006, 2008) |
| AB2 | Anjohibe cave | 131 | −15.5300 | 46.8800 | Madagascar | Scroxton et al. (2017) |
| AB3 | Anjohibe cave | 131 | −15.5300 | 46.8800 | Madagascar | Burns et al. (2016) |
| ANJB-2 | Anjokipoty cave | 131 | −15.5300 | 46.8800 | Madagascar | Voarintsoa et al. (2017c) |
| MA3 | Anjohibe cave | 131 | −15.5300 | 46.8800 | Madagascar | Voarintsoa et al. (2017a) |
| MAJ-5 | Anjokipoty cave | 131 | −15.5784 | 46.7344 | Madagascar | Voarintsoa et al. (2017c) |
| CC-1_2004 | Antro del Corchia | 840 | 43.9800 | 10.2200 | Italy | Drysdale et al. (2004) |
| CC-1_2009, CC-5_2009, CC-7 | Antro del Corchia | 840 | 43.9800 | 10.2200 | Italy | Drysdale et al. (2009) |
| BT-1, BT-2.1, BT-2.2, BT-2.3, BT-2.4, BT-2.5, BT-4, BT-6, BT-8, BT-9 | Antro del Corchia | 840 | 43.9800 | 10.2200 | Italy | Drysdale et al. (2005) |
| BCC-2, BCC-4, BCC-6, BCC_composite | Antro del Corchia | 840 | 43.9800 | 10.2200 | Italy | Drysdale et al. (2007) |
| BCC-8, BCC-10 | Antro del Corchia | 840 | 43.9800 | 10.2200 | Italy | Drysdale et al. (2005) |
| BRC01-07 | Bourgeos-Delaunay cave | 100 | 45.6678 | 0.5133 | France | Couchoud et al. (2009) |
| Boss, BFM-9, F2 | Brown’s Folly mine | 150 | 51.3800 | −2.3700 | England (UK) | Baldini (2001), Baldini et al. (2005) |
| RL4_2006 | Buca della Renella | 300 | 44.0800 | 10.2100 | Italy | Zanchetta et al. (2016) |
| RL4_2016 | Buca della Renella | 300 | 44.0800 | 10.2100 | Italy | Zanchetta et al. (2016) |
| RL4_2018 | Buca della Renella | 300 | 44.0800 | 10.2100 | Italy | Zanchetta et al. (2016) |
| BCC-2, BCC-4, BCC-6, BCC_composite | Bunker cave | 600 | 37.9825 | −79.5894 | USA | Hardt et al. (2010) |
| BCC-8, BCC-10 | Buckeye creek | 600 | 37.9825 | −79.5894 | USA | Springer et al. (2014) |
| BMS1 | Bue Marino cave | 0 | 40.2467 | 9.6228 | Italy | Columbu et al. (2017) |
| Buffalo Cave Flowstone | Buffalo cave | 1140 | −24.1428 | −49.1569 | Brazil | Bernal et al. (2016) |
| BA02 | Bukt Assam cave | 150 | 4.0300 | 114.8000 | Malaysia | Carolin et al. (2013) |
| BA03 | Bukt Assam cave | 150 | 4.0300 | 114.8000 | Malaysia | Chen et al. (2016) |
| BA04 | Bukt Assam cave | 150 | 4.0300 | 114.8000 | Malaysia | Partin et al. (2007) |
| Bu1, Bu2, Bu4, Bu6, BuStack | Bunkers stack | 184 | 51.3675 | 7.6647 | Germany | Fohlmeister et al. (2012) |
| Calcite | Calcite cave | −46.0172 | −33.3925 | −82.5186 | USA | Lorrey et al. (2008) |
| V3 | Cango cave | 31.7500 | 29.8852 | −98.6208 | USA | Feng et al. (2014) |
| COB-01-02 | Cave Without a Name | 31.7500 | −110.7500 | −82.5186 | USA | Lorrey et al. (2008) |
| CWN4 | Cave Without a Name | 377 | 29.8852 | −98.6208 | USA | Feng et al. (2014) |
| Entity name | Site name | Elv (m) | Lat (°) | Long (°) | Region | Citations |
|-------------|-----------|---------|---------|---------|--------|-----------|
| CC-1        | Ceremosnja cave | 530 | 44.4000 | 21.6500 | Republic of Serbia | Kacanski et al. (2001) |
| Chau-stm6   | Chauvet cave | 240 | 44.2300 | 4.2600 | France | Genty et al. (2006) |
| CHIL-1      | Chilibrillo cave | 60 | 9.1741 | -79.6164 | Panama | Lachniet (2004) |
| CL26        | Clamouse cave | 110 | 43.7100 | 3.5500 | France | McDermott et al. (1999) |
| Cla4        | Clamouse cave | 110 | 43.7100 | 3.5500 | France | Plagnes et al. (2002) |
| FC12-12, FC12-14, FC12-15 | Clearwater cave | 120 | 4.1000 | 114.8333 | Malaysia | Carolin et al. (2016) |
| Squeeze1    | Clearwater/Wind caves connection | 4.1000 | 114.8300 | Malaysia | Meckler et al. (2012) |
| T5          | Cold Air cave | 1420 | -24.0000 | 29.1833 | South Africa | Repinski et al. (1999), Stevenson et al. (1999) |
| T7_1999     | Cold Air cave | 1420 | -24.0000 | 29.1833 | South Africa | Holmgren et al. (1999), |
| T7_2001     | Cold Air cave | 1420 | -24.0000 | 29.1833 | South Africa | Lee-Thorp et al. (2001) |
| T7_2013     | Cold Air cave | 1420 | -24.0000 | 29.1833 | South Africa | Sundqvist et al. (2013) |
| T8          | Cold Air cave | 1420 | -24.0000 | 29.1833 | South Africa | Holmgren et al. (2003) |
| ESP03       | Cova da Arcoia | 1240 | 42.6100 | -7.0900 | Spain | Railsback et al. (2011) |
| CC3         | Crag cave | 60 | 52.2500 | -9.4300 | Ireland | McDermott et al. (1999), McDermott (2001) |
| ASR, ASM    | Cueva de Asiul | 285 | 43.3200 | -3.5900 | Spain | Smith et al. (2016) |
| CBD-2       | Cueva del Diablo | 1030 | 18.1920 | -99.9210 | Mexico | Bernal et al. (2011) |
| CUR4        | Curupira cave | 420 | -15.2002 | -56.7839 | Brazil | Novello et al. (2016) |
| DAN-D       | Dandak cave | 400 | 19.0000 | 82.0000 | India | Berkelhammer et al. (2010), Sinha et al. (2007) |
| DP1_2013    | Dante cave | 1420 | -19.4000 | 17.8833 | Namibia | Sletten et al. (2013) |
| DP1_2016    | Dante cave | 1420 | -19.4000 | 17.8833 | Namibia | Voarintsoa et al. (2017b) |
| DY-1        | Dayu cave | 870 | 33.1330 | 106.3000 | China | Tan et al. (2009) |
| S3          | Delfore cave | 150 | 17.1667 | 54.0833 | Oman | Burns (2002) |
| DSSG-4      | DeSoto caverns | 150 | 33.3722 | -86.3667 | USA | Aharon et al. (2013) |
| DH2, DH2-D, DH2-E Terminal1, DH2-E Terminal2 | Devils Hole | 719 | 36.4254 | -116.2920 | USA | Moseley et al. (2016) |
| Dim-E2, Dim-E3, Dim-E4 | Dim cave | 232 | 36.5340 | 32.1056 | Turkey | Ünal-İmer et al. (2015) |
| DV2         | Diva cave | 680 | -12.3667 | -41.5667 | Brazil | Novello et al. (2012) |
| D3, D4      | Dongge cave | 680 | 25.2800 | 108.0800 | China | Yuan (2004) |
| D8          | Dongge cave | 680 | 25.2800 | 108.0800 | China | Cheng et al. (2016b) |
| Doubtful    | Doubtful Xanadu | 960 | -45.3735 | 167.0476 | New Zealand | Lorrey et al. (2008) |
| ARTEMISA    | Ejualve cave | 1240 | 40.4500 | -0.3500 | Spain | Pérez-Mejías et al. (2017) |
| HOR         | Ejualve cave | 1240 | 40.4500 | -0.3500 | Spain | Moreno et al. (2017) |
| TKS         | Entrische Kirche cave | 2119 | 47.1600 | 13.1500 | Austria | Meyer et al. (2008) |
| GEX-SPA     | Excentrica cave | 100 | 37.1000 | -7.7700 | Portugal | Ponte et al. (2017) |
| ED1         | Exhaleair cave | 685 | -41.2833 | 172.6330 | New Zealand | Hellstrom et al. (1998) |
| FS2_2010    | Fort Stanton cave | 1864 | 33.5067 | -105.4430 | USA | Asmerom et al. (2010) |
| FS2_2012    | Fort Stanton cave | 1864 | 33.5067 | -105.4430 | USA | Polyak et al. (2012) |
| FG01        | Fukugaguchi cave | 170 | 36.9917 | 137.8000 | Japan | Sone et al. (2013) |
| FR-0510     | Furon cave | 480 | 29.2289 | 107.9036 | China | H.-C. Li et al. (2011) |
| FR-5        | Furon cave | 480 | 29.2289 | 107.9036 | China | T.-Y. Li et al. (2011) |
| GG1, GG2    | Gardener’s Gut | 120 | -37.7394 | 175.1033 | New Zealand | Williams et al. (2004) |
| GC08        | Green Cathedral cave | 4.2333 | 114.9250 | Malaysia | Meckler et al. (2012) |
| CR1         | Grotta di Carburanegli | 22 | 38.1671 | 13.1615 | Italy | Frisia et al. (2006), Madonia et al. (2005) |
| ER76        | Grotta di Ernesto | 1167 | 45.9667 | 11.6500 | Italy | Scholz et al. (2012) |
Table 1. Continued.

| Entity name | Site name | Elv (m) | Lat (°) | Long (°) | Region     | Citations                                                                 |
|-------------|-----------|---------|---------|----------|------------|---------------------------------------------------------------------------|
| GP2         | Grotte de Piste | 1260    | 33.8400 | −4.0900  | Morocco     | Wassenburg et al. (2016)                                                 |
| stm2, stm4  | Gueldaman cave  | 507     | 36.4333 | 4.5667   | Algeria     | Ruan et al. (2016)                                                       |
| GT05-5      | Guillotine cave | 740     | −42.3108| 172.2178 | New Zealand | Whittaker (2008)                                                         |
| SSC01, SCH02| Gunung-buda cave (snail shell cave) | 150 | 4.0330  | 114.8000 | Malaysia     | Cobb et al. (2007), Moerman et al. (2013, 2014), Partin et al. (2007, 2013b) |
| Han-9       | Han-sur-Lesse cave | 180    | 50.1164 | 5.1884   | Belgium     | Vansteenberge et al. (2016)                                               |
| Han-stm1    | Han-sur-Lesse cave | 180    | 50.1164 | 5.1884   | Belgium     | Genty et al. (1999)                                                       |
| Han-stm5b   | Han-sur-Lesse cave | 180    | 50.1164 | 5.1884   | Belgium     | Genty et al. (1998)                                                       |
| HS4_2008    | Heshang cave    | 294     | 30.4500 | 110.4167 | China       | Hu et al. (2008)                                                         |
| HS4_2013    | Heshang cave    | 294     | 30.4500 | 110.4167 | China       | Liu et al. (2013)                                                        |
| HOL-10      | Höllöch im Mahdental | 1240  | 47.3781 | 10.1506  | Germany     | Moseley et al. (2015)                                                    |
| HOL-7, HOL-16, HOL-17, HOL-18, HOL-16-17, HOL-comp | Höllöch im Mahdental | 1240 | 47.3781 | 10.1506  | Germany     | Moseley et al. (2014)                                                    |
| HW3         | Hollywood cave  | 130     | −41.9500| 171.4667 | New Zealand | Whittaker et al. (2011)                                                   |
| H5          | Hoti cave      | 800     | 23.0833 | 36.3275  | Morocco     | Neff et al. (2001)                                                       |
| HY1, HY2, HY3 | Huangye cave   | 1650    | 33.5833 | 105.1167 | China       | Tan et al. (2010)                                                        |
| MSD, MSL, PD, YT, H82 | Hulu cave     | 90      | 32.5000 | 119.1700 | China       | Wang (2001)                                                              |
| JAR7, JAR14, JAR13 | Jaragúa cave | 570     | −21.0830| −56.5830 | Brazil      | Novello et al. (2017)                                                    |
| Jeita-1, Jeita-2, Jeita-3 | Jeita cave    | 100     | 33.9500 | 35.6500  | Lebanon     | Cheng et al. (2015)                                                      |
| AF12        | Jerusalem west cave | 700 | 31.7833 | 35.1500  | Israel      | Frumkin et al. (1999, 2000)                                               |
| JHU-1       | Jhumar cave    | 600     | 18.8667 | 81.8667  | India       | Sinha et al. (2011)                                                      |
| C996-1, C996-2 | Juxian cave  | 1495    | 33.5667 | 109.1000 | China       | Cai et al. (2010b)                                                       |
| JX-2, JX-10 | Juxtlahuaca cave | 934   | 17.4000 | −99.2000 | Mexico      | Lachniet et al. (2013)                                                   |
| JX-6        | Juxtlahuaca cave | 934   | 17.4000 | −99.2000 | Mexico      | Lachniet et al. (2012)                                                   |
| JX-7        | Juxtlahuaca cave | 934   | 17.4000 | −99.2000 | Mexico      | Lachniet et al. (2017)                                                   |
| KL 3        | Kalakot cave   | 826     | 33.2219 | 74.4258  | India       | Kotlia et al. (2016)                                                     |
| Kanaan_MIS5 | Kanaan cave    | 98      | 33.9069 | 35.6069  | Lebanon     | Nehme et al. (2015)                                                      |
| Kanaan_MIS6 | Kanaan cave    | 98      | 33.9069 | 35.6069  | Lebanon     | Nehme et al. (2018)                                                      |
| GK-09-02    | Kapsia cave    | 700     | 37.6233 | 22.3339  | Greece      | Finné et al. (2014)                                                      |
| K1, K3      | Katerloch cave | 900     | 47.0833 | 15.5500  | Austria     | Boch et al. (2009)                                                       |
| KS06-A-H, KS06-A, KS06-B, KS08-1-H, KS08-2-H, KS08-2 | Kesang cave   | 2000    | 42.8700 | 81.7500  | China       | Cheng et al. (2012, 2016a)                                                |
| KS08-2-MIS3, KS08-6 | Kesang cave | 2000    | 42.8700 | 81.7500  | China       | Cheng et al. (2016a)                                                     |
| KC-1, KC-3, KC-Composite | Kinderlinskaya cave | 240 | 54.1500 | 56.8500  | Russia      | Baker et al. (2017)                                                      |
| PFU6        | Klapferloch cave | 1140  | 46.9500 | 10.5500  | Austria     | Boch et al. (2011)                                                       |
| SPA_126, SPA_49 | Kleegruben cave | 2165 | 47.0800 | 11.6700  | Austria     | Spöl et al. (2006)                                                      |
| KNI-51-0, KNI-51-3, KNI-51-4, KNI-51-7, KNI-51-10, KNI-51-A2-side1, KNI-51-A2-side2, KNI-51-C, KNI-51-F, KNI-51-G, KNI-51-H, KNI-51-I, KNI-51-J, KNI-51-N, KNI-51-O | KNI-51 cave | 100     | −15.1800| 128.3700 | Australia     | Denniston et al. (2013a)                                                 |
| Entity name   | Site name            | Elv (m) | Lat (°)     | Long (°)     | Region     | Citations                                      |
|--------------|----------------------|---------|-------------|--------------|------------|-----------------------------------------------|
| KNI-51-11    | KNI-51 cave          | 100     | −15.1800    | 128.3700     | Australia  | Denniston et al. (2015, 2016)                 |
| K11          | Korallgrottan cave   | 540     | 64.8800     | 14.0000      | Sweden     | Sundqvist et al. (2010)                       |
| BW-1         | Kulishu cave         | 610     | 39.6800     | 115.6500     | China      | Ma et al. (2012)                              |
| Min-stm1     | La Mine cave         | 975     | 36.0030     | 9.6800       | Tunisia    | Genty et al. (2006)                           |
| L4           | Labyrinthgrottan cave| 730     | 66.0600     | 14.6800      | Sweden     | Sundqvist et al. (2007)                       |
| LH-70s-1     | Lancaster Hole       | 294     | 54.2209     | −2.5168      | England (UK) | Atkinson and Hopley (2013)                  |
| LH-70s-2, LH-70s-3 | Lancaster Hole | 294   | 54.2209     | −2.5168      | England (UK) | Atkinson and Hoffman (unpublished)            |
| LD12         | Lapa Doce cave       | 680     | −12.3667    | −41.5667     | Brazil     | Novello et al. (2012)                         |
| LG11, LG3    | Lapa grande cave     | 590     | −14.4200    | −44.3660     | Brazil     | Strikis et al. (2011)                         |
| LSF16, LSF3  | Lapa semi fum cave   | 341     | −16.1503    | −44.6281     | Brazil     | Strikis et al. (2015)                         |
| L03          | Larshullet cave      | 400     | 66.0000     | 14.0000      | Norway     | Linge et al. (2009b)                          |
| Leany        | Leány cave           | 420     | 47.7000     | 18.8400      | Hungary    | Demény et al. (2013)                         |
| LC-2         | Lehman caves         | 2080    | 39.0100     | −114.2200    | USA        | Shakan et al. (2011)                          |
| LMC-14, LMC-21| Lehman caves       | 2080    | 39.0100     | −114.2200    | USA        | Lachniet et al. (2014)                       |
| LC-1         | Leviathan cave       | 2400    | 37.8900     | −115.5800    | USA        | Lachniet et al. (2014)                       |
| LR06-B1_2009, LR06-B3_2009 | Liang Luar cave | 550 | −8.5300     | 120.4300    | Indonesia | Griffiths et al. (2009)                      |
| LR06-B1_2016, LR06-B3_2016 | Liang Luar cave | 550 | −8.5300     | 120.4300    | Indonesia | Griffiths et al. (2016)                      |
| LR06-B3_2013, LR06-C2, LR06-C3_2013, LR06-C5, LR06-C6, LL_Comp_2013 | Liang Luar cave | 550 | −8.5300     | 120.4300    | Indonesia | Ayliffe et al. (2013)                        |
| LR07-A8, LR07-A9, LR07-E11 | Liang Luar cave | 550 | −8.5300     | 120.4300    | Indonesia | Griffiths et al. (2013)                      |
| LR07-E1, LR06-C3_2011, LR07-E1-D | Liang Luar cave | 550 | −8.5300     | 120.4300    | Indonesia | Lewis et al. (2011)                          |
| LII4, LII4-KH | Lobatse cave         | 1200    | −25.2100    | 25.6800      | Botswana   | Holmgren et al. (1994, 1995)                  |
| ME-12        | Ma’ale Efrayim cave  | 250     | 32.0660     | 35.3952      | West Bank  | Vaks et al. (2003)                            |
| MC01         | Macal Chasm          | 530     | 16.8830     | −89.1080     | Belize     | Akers et al. (2016), Webster et al. (2007)   |
| MC-S1, MC-S2 | Mairs cave           | 475     | −32.1600    | 138.8300     | Australia  | Treble et al. (2017)                          |
| S1           | Mavri Trypa cave     | 70      | 36.7360     | 21.7596      | Greece     | Finné et al. (2017)                          |
| KM-A         | Mawmluh cave         | 1160    | 25.2622     | 91.8817      | India      | Berkelhammer et al. (2013), Breitenbach et al. (2015) |
| MAW-6        | Mawmluh cave         | 1160    | 25.2622     | 91.8817      | India      | Lechleitner et al. (2017)                     |
| MWS-1        | Mawmluh cave         | 1160    | 25.2622     | 91.8817      | India      | Breitenbach et al. (2015), Dutt et al. (2015) |
| MAXS         | Max’s cave           | 325     | −37.7394    | 175.1033     | New Zealand| Williams et al. (2004)                        |
| ML1          | McLean’s cave        | 300     | 38.0700     | −120.4200    | USA        | Oster et al. (2015)                           |
| MB-2, MB-3, MB-5, MB-6 | Milchbach cave | 1840 | 46.6167     | 8.0830       | Switzerland | Luetscher et al. (2011)                      |
| MC3          | Moaning cave         | 520     | 38.0717     | −120.4660    | USA        | Oster et al. (2009, 2015)                     |
| MOD-22       | Modric cave          | 32      | 44.2568     | 15.5372      | Croatia    | Rudzka et al. (2012)                         |
| MO-1         | Molinos cave         | 1050    | 40.7925     | −0.4492      | Spain      | Moreno et al. (2017)                         |
| MO-7         | Molinos cave         | 1050    | 40.7925     | −0.4492      | Spain      | Moreno et al. (2017), Muñoz et al. (2015)    |
| M1-5         | Moomi cave           | 400     | 12.5000     | 54.0000      | Yemen      | Shakun et al. (2007)                         |
Table 1. Continued.

| Entity name | Site name | Elv (m) | Lat (°) | Long (°) | Region | Citations |
|-------------|-----------|---------|---------|----------|--------|-----------|
| Mun-stm2, Mun-stm1 | Munagamanu cave | 475 | 15.1500 | 77.9200 | India | Genty et al. (unpublished) |
| NBJ | Natural Bridge | 306 | 29.6900 | -98.3400 | USA | Wong et al. (2015) |
| MD3 | Nettled bed cave | 390 | -41.2500 | 172.6330 | New Zealand | Hellstrom et al. (1998) |
| Gib04a | New St Michael’s cave | 325 | 36.1261 | -5.3455 | (UK) | Mathey et al. (2008, 2010) |
| FM3, Oks82 | Okshola cave | 165 | 67.0000 | 15.0000 | Norway | Linge et al. (2009a) |
| OCNM02-1 | Oregon caves national monument | 1300 | 42.0981 | -123.4070 | USA | Ersek et al. (2012) |
| PX7 | Paixão cave | 165 | -12.6182 | -41.0184 | Brazil | Strikis et al. (2015) |
| PAL3, PAL4 | Palestina cave | 870 | -5.9200 | -77.3500 | Peru | Apaéstegui et al. (2014) |
| PAR01, PAR03, PAR06, PAR07, PAR08, PAR16, PAR24 | Paraiso cave | 60 | -4.0667 | -55.4500 | Brazil | Wang et al. (2017) |
| ALHO6 | Pau d’Alho cave | 340 | -15.2055 | -56.8000 | Brazil | Jaqueto et al. (2016), Novello et al. (2016) |
| PDR-1 | Perdida cave | 350 | 18.0000 | -67.0000 | Puerto Rico | Winter et al. (2011) |
| Candela | Pindal cave | 24 | 43.4000 | -4.5300 | Spain | Moreno et al. (2010), Rudzka et al. (2011) |
| PC-1 | Pinnacle cave | 1792 | 35.9700 | -115.5000 | USA | Lachniet et al. (2011) |
| YD01 | Pippipkin Pot cave | 320 | 54.2143 | -2.5123 | England (UK) | Atkinson and Hopley (2013), Daley et al. (2011) |
| POS-STM-4 | Postojna cave | 529 | 45.7700 | 14.2000 | Slovenia | Genty et al. (1998) |
| Q5 | Qunf cave | 650 | 17.1667 | 54.3000 | Oman | Fleitmann et al. (2007) |
| RN1, RN4 | Rainha cave | 100 | -5.6000 | -37.7330 | Brazil | Cruz et al. (2009) |
| Ruakuri C | Ruakuri cave | 80 | -38.2667 | 175.0667 | New Zealand | Williams et al. (2004) |
| Merc-1, Asfa-3 | RukieSSa cave | 1618 | 8.6036 | 40.3772 | Ethiopia | Asrat et al. (2008), Baker et al. (2007) |
| SAH-A, SAH-B, SAH-AB | Sahiya cave | 1190 | 30.6000 | 78.8670 | India | Sinha et al. (2015) |
| SB-10, SB-26, SB-27, SB-43, SB-44, SB-49 | Sanbao cave | 1900 | 31.6670 | 110.4330 | China | Dong et al. (2010) |
| SB-12, SB-14, SB-32, SB-58 | Sanbao cave | 1900 | 31.6670 | 110.4330 | China | Cheng et al. (2016b) |
| MF-3 | Schafsloch cave | 1890 | 47.2333 | 9.3833 | Switzerland | Häuselmann et al. (2015) |
| SCH-5 | Schneckenloch cave | 1285 | 47.4333 | 9.8667 | Austria | Moseley et al. (2015) |
| SCH-7 | Schneckenloch cave | 1285 | 47.4333 | 9.8667 | Austria | Boch et al. (2011) |
| SC02, SC03 | Secret cave | 250 | 4.0848 | 114.8503 | Malaysia | Carolin et al. (2013) |
| SE09-6 | Sesu cave | 794 | 42.4600 | 0.0400 | Spain | Bartolomé et al. (2015) |
| 7H, 7H-2, 7H-3 | Sieben Hengste cave | 1955 | 46.7500 | 7.8100 | Switzerland | Luetscher et al. (2015) |
| MAR_L | Skala Marion cave | 41 | 40.6387 | 24.5144 | Greece | Psomiadis et al. (2018) |
| So-1 | Sofular cave | 700 | 41.4200 | 31.9300 | Turkey | Fleitmann et al. (2009) |
| 2-6 | Soreq cave | 400 | 31.7558 | 35.0224 | Israel | Orland et al. (2009) |
| 2N | Soreq cave | 400 | 31.7558 | 35.0224 | Israel | Orland et al. (2012) |
| Soreq-composite | Soreq cave | 400 | 31.7558 | 35.0224 | Israel | Grant et al. (2012) |
| SG95 | Soylegrotta cave | 280 | 66.0000 | 14.0000 | Norway | Linge et al. (2001) |
| SPA12, SPA70, SPA128, SPA127, COMNISPA II, SPA133 | Spannagel cave | 2310 | 47.0800 | 11.6700 | Austria | Fohliemeister et al. (2013) |
| SPA121 | Spannagel cave | 2310 | 47.0800 | 11.6700 | Austria | Spödl et al. (2008) |
| SZ2 | Suozzi cave | 700 | 32.4300 | 107.1700 | China | Zhou et al. (2008) |
| TM0, TM2 | Tamboril cave | 200 | -16.0000 | -47.0000 | Brazil | Wortham et al. (2017) |
| Taurus | Taurius cave | 230 | -15.5333 | 167.0167 | Vanuatu | Partin et al. (2013a) |
### Table 1. Continued.

| Entity name | Site name | Elv (m) | Lat (°) | Long (°) | Region | Citations |
|-------------|-----------|---------|---------|----------|--------|-----------|
| Aurora      | Te Anau Fiordland | 320 | −45.2800 | 167.7000 | New Zealand | Lorrey et al. (2008) |
| Te Reinga A | Te Reinga cave | −38.8200 | 177.5200 | New Zealand | Lorrey et al. (2008) |
| Te Reinga B |            |         |         |          |        |           |
| TM-18a, TM-18b | Tiamen | 4800 | 30.9167 | 90.0667 | China | Cai et al. (2012) |
| TM-2, TM-5  | Tiamen   | 4800 | 30.9167 | 90.0667 | China | Cai et al. (2010a) |
| T1          | Timita cave | 1900 | 29.8381 | 82.0336 | India | Sinha et al. (2005) |
| TC1         | Tityana cave | 1470 | 30.6419 | 77.6521 | India | Joshi et al. (2017) |
| TON-1, TON-2 | Tonnel'nya cave | 3226 | 38.4000 | 67.2300 | Uzbekistan | Cheng et al. (2016a) |
| TR5         | Torrinha cave | 680 | −12.3667 | −41.5667 | Brazil | Novello et al. (2012) |
| Trio        | Trió cave | 275 | 46.1100 | 18.1500 | Hungary | Demény et al. (2017a), Siklósy et al. (2009) |
| Chaac       | Tzabnah cave | 20 | 20.7300 | −89.7160 | Mexico | Medina-Elizalde et al. (2010) |
| SU032       | Uamh an Tartair | 220 | 58.1400 | −4.9300 | Scotland | Baker et al. (2012) |
| SU967       | Uamh an Tartair | 220 | 58.1400 | −4.9300 | Scotland | Baker et al. (2011) |
| PU-2        | Ursilor cave | 482 | 46.5537 | 22.5695 | Romania | Onac et al. (2002) |
| VSPM1       | Valmiki cave | 420 | 15.1500 | 77.8167 | India | Raza et al. (2017) |
| VSPM4       | Valmiki cave | 420 | 15.1500 | 77.8167 | India | Lone et al. (2014) |
| Ville-c1    | Villars cave | 175 | 45.4300 | 0.7800 | France | Wainer et al. (2011) |
| Ville-stm1  | Villars cave | 175 | 45.4300 | 0.7800 | France | Labuhn et al. (2015) |
| Ville-stm11 | Villars cave | 175 | 45.4300 | 0.7800 | France | Genty et al. (2006) |
| Ville-stm14 | Villars cave | 175 | 45.4300 | 0.7800 | France | Genty et al. (2010), Wainer et al. (2009) |
| Ville-stm27 | Villars cave | 175 | 45.4300 | 0.7800 | France | Genty et al. (2003) |
| Ville-stm6  | Villars cave | 175 | 45.4300 | 0.7800 | France | Genty (unpublished) |
| Ville-stm9  | Villars cave | 175 | 45.4300 | 0.7800 | France | Genty et al. (2003, 2010) |
| WS-B        | Wah Shikhar cave | 1290 | 25.2500 | 91.8667 | India | Sinha et al. (2011) |
| Waiatu      | Waiatu cave | 100 | −46.0000 | 167.7300 | New Zealand | Lorrey et al. (2008) |
| WP-1        | Wazpretti cave | 100 | −42.3108 | 171.4000 | New Zealand | Williams et al. (2005) |
| WSC-97-10-5 | White Scar cave | 255 | 54.1656 | −2.4419 | England (UK) | Atkinson and Hopley (2013), Daley et al. (2011) |
| WR5         | Whiterock cave | 4.1500 | 14.5000 | 114.8600 | Malaysia | Meckler et al. (2012) |
| W5          | Wolkerberg cave | 1450 | −24.1000 | 29.8800 | South Africa | Holzkämper et al. (2009) |
| XB1-3, XB1-4, XB1-7, XB1-26, XB1-27, XB1-29, XB1-48, XB1-65 | | | | | |
| XL-1        | Xinglong cave | 710 | 40.5000 | 117.5000 | China | Duan et al. (2016) |
| XV07-8      | Xinya cave | 1250 | 30.7500 | 109.4700 | China | J. Y. Li et al. (2017) |
| XY-2        | Xinya cave | 1250 | 30.7500 | 109.4700 | China | Li et al. (2007) |
| JFYK7       | Yangkou cave | 2140 | 29.0330 | 107.1833 | China | Han et al. (2016), T.-Y. Li et al. (2017), Zhang et al. (2017) |
| YK5, YK12, YK23, YK47, YK61 | Yangkou cave | 2140 | 29.0330 | 107.1833 | China | Li et al. (2014) |
| YOKG        | Yok Balum cave | 336 | 16.2086 | −89.0735 | Belize | Ridley et al. (2015) |
| YOKI        | Yok Balum cave | 336 | 16.2086 | −89.0735 | Belize | Kennett et al. (2012) |
| ZLP1, ZLP2  | Zhuluping cave | 1217 | 26.0167 | 104.0950 | China | Huang et al. (2016) |
SISAL (Speleothem Isotope Synthesis and Analysis) is an international working group set up in 2017 under the auspices of the Past Global Changes (PAGES) programme (http: //pastglobalchanges.org/ini/wg/sisal, last access: 4 September 2018). The aim of the working group is to compile the many hundreds of speleothem isotopic records worldwide, paying due attention to careful screening and metadata documentation, the construction of standardized age models, and age-model uncertainties, in order to produce a public-access database that can be used for palaeoclimate reconstruction and for climate-model evaluation. In this paper, we document the first publicly available version of the SISAL database, focusing on describing its structure and contents including the information that has been included to facilitate quality control.

2 Data and methods

2.1 Compilation of data

The database contains stable carbon and oxygen isotope measurements made on speleothems, as well as supporting metadata to facilitate the interpretation of these records. All available speleothem data are included, and no attempt was made to screen records on the basis of the time period covered, the resolution of the records, or the quality of the data or age models. Adequate metadata are provided to allow database users to select the records that are suitable for a particular type of analysis. The raw data were either provided by members of the SISAL working group or extracted from data lodged in PANGAEA or from the National Centres for Environmental Information. Additional information on the records was compiled from publications. All the records in the current version of the database (SISAL v1) are listed and described in Table 1.

2.2 Structure of the database

The data are stored in a relational database (MySQL), which consists of 14 linked tables, specifically site, entity, sample, dating, dating lamina, gap, hiatus, original chronology, δ¹³C, δ¹⁸O, entity link reference, reference, composite link entity and notes. Figure S1 shows the relationships between these tables. A detailed description of the structure and content of each of the tables is given below. The details of the predefined lists for all fields can be found in Table S1.

2.2.1 Site metadata (table name: site)

A site is defined as the cave or cave system from which speleothem records have been obtained. A site may therefore be linked to several speleothem records, where each record is treated as a separate entity. The site table contains basic metadata about the cave or cave system, including site ID, site name, latitude, longitude, elevation, geology, rock age and monitoring (see Table S2). The elevation is that of the cave itself, not the elevation of the land surface above the cave. Since the elevation of the land surface can be obtained from other sources, we include the cave elevation to facilitate making additional lapse rate corrections for oxygen isotopes for high elevation sites (Bowen and Wilkinson, 2002). This also allows an estimation of the depth of the overburden above the speleothem site, and hence an estimate of the time taken for water to reach the cave. The description of the geology and the age of the rock formation (rock_age) is given because this is important for understanding the degree of permeability of the material above the cave. Primary porosity decreases and fracture flow increases as rocks age, which in turn affects the likely speed at which water flows through the host rock and reaches the cave system. The geology field is also useful because it gives an indication of whether the cave is formed in Mg-rich rocks (e.g. dolomite) and thus whether the speleothems are likely to be formed of aragonite, which would require special consideration in terms of oxygen and carbon isotope comparisons with that of calcite (see also Table S3). Only a limited number of descriptive terms are allowed for each field. The age of rock formation follows the standard era, period, epoch terminology as defined by the International Commission on Stratigraphy in 2015 (Cohen et al., 2015). The database includes information on whether the cave site has been monitored: positive returns in this field mean that monitoring of in-cave environmental parameters (e.g. cave air temperature) and/or cave drip chemistry has been carried out periodically for at least one entire season (as opposed to one-off measurements of in-cave conditions when the speleothem was collected). The database does not contain monitoring data, but inclusion of this field facilitates researchers being able to contact the original data providers about monitoring information, which can be useful in understanding if a cave is likely to contain speleothems that have been deposited close to isotopic equilibrium.

2.2.2 Entity metadata (table name: entity)

Each speleothem (or composite speleothem record) has a unique identifier and a unique name. The entity metadata table (Table S3) provides information on the cave environment that can affect speleothem formation. This includes the thickness of the cover above the speleothem, which might affect the time taken for water to reach the drip site feeding the speleothem and hence the responsiveness of the record to individual rain events or seasonal patterns of precipitation (Fairchild and Baker, 2012). The distance of the speleothem from the cave entrance is provided, which, depending on the morphology of a cave, can be a useful indicator of cave ventilation (direct air advection). Ventilation is important as it can control cave air temperature, humidity, evaporation and pCO₂ levels (Fairchild and Baker, 2012; Frisia et al., 2011; Spötl et al., 2005; Tremaine et al., 2011). The entity table also contains a field to document whether any tests have been
carried out to establish whether there is oxygen and carbon isotope quasi-equilibrium between the drip water (CO$_2$–H$_2$O system) and the speleothem (CaCO$_3$). There are several such tests (see for example Hendy, 1971; Johnston et al., 2013; Mickler et al., 2006; Tremaine et al., 2011), but no attempt is made to identify which test has been applied in the database. The drip type (e.g. seepage flow, seasonal drip, vadose flow; Smart and Friederich, 1987) also provides useful hydrological information: seepage flow shows a small inter-annual variability of discharge and the speleothem record will therefore more likely reflect a long-term average state over several years; other drip types, such as seasonal drip, will indicate the potential to record seasonal or individual rainfall events.

The main focus of the SISAL database is stable isotope measurements, but the entity metadata table also contains information on the kinds of measurements that have been made for a specific speleothem. Only the stable isotope measurements are currently archived in the database. However, listing the range of data available from any speleothem will facilitate future updates of the database to include other types of measurements apart from stable isotopes (i.e. trace elements) and will help researchers in locating speleothems where multiple types of measurements have been done. The entity metadata table contains four fields to facilitate data traceability. The first two fields give the name of the person who was responsible for collating the data, and a DOI or URL for the original data. Some records have been partially or entirely updated since first being published. Although these records are included for data traceability, the entity_status field indicates whether they have been partially updated (e.g. with additional samples and/or improved age models) or completely superseded by a new record. The field corresponding_current indicates which entity (or entities) provides updated information. Information on original publications on specific speleothems is given in the reference table (see Sect. 2.2.11).

2.2.3 Sample metadata (table name: sample)

The sample metadata table (Table S4) contains information on the location of the sample with respect to a reference point, where the reference point can be either the top or the base of the speleothem. It also provides information on the thickness and mineralogy (calcite, secondary calcite, aragonite, vaterite, mixed, not known) of each sample. Since some samples may have mixed mineralogy, it also provides information on whether a correction for aragonite has been applied to $\delta^{18}$O or $\delta^{13}$C, due to different phosphoric acid fractionation factors.

2.2.4 Dating information (table name: dating)

The dating information table (Table S5) provides information on the radiometric dates used to construct the original age model for each of the speleothem entities, including type of radiometric date (e.g. U series), depth of dated sample, thickness of dated sample and sample weight. Dates that are used to anchor sequences that are dated by lamina counting (see Sect. 2.2.5) are included in the dating information table and identified in date type as an event (i.e. the start or end of a laminated sequence). The degree of precision varies between different dating methods and techniques, for example mass spectrometric U/Th dating generally produces a more precise age than the alpha spectrometry U/Th data method. So the inclusion of the dating method provides a basic measure of the reliability, in terms of analytical precision, of any given date. Sample thickness also influences the dating uncertainty, because thicker samples will integrate more material of different age. Similarly, sample weight can influence precision: samples younger than a few thousand years may contain very low levels of the daughter isotope $^{230}$Th (whose accumulation by radioactive decay provides the measure of the sample’s age), and so require more material to provide an accurate and precise result. The content of $^{232}$Th is included in the dating information table because this value is used for the detrital correction of initial $^{230}$Th. Sample mineralogy is also included because this affects the reliability of individual dates (e.g. samples from re-crystallized secondary calcite are not reliable because of the loss of uranium; Bajo et al., 2016).

We provide both the original uncorrected age and the corrected age for each date. The corrected U/Th age is adjusted for detrital contamination; the corrected calibrated $^{14}$C age is adjusted for dead carbon. The correction factors used to derive the corrected U/Th or $^{14}$C age are included in the dating information table. The decay constant used to calculate the U/Th ages is given because the values used have changed through time (Cheng et al., 2000, 2013; Edwards et al., 1987; Ivanovitch and Harmon, 1992). The calibration curve used to convert radiocarbon ages to calendar years in the original publication is also given. Several different standards have been used in the original publications for the modern reference state (e.g. BP(1950), b2k, CE / BCE or the year when U/Th chemical separation was performed) but all of these have been converted to BP(1950) in the database.

Some of the dates listed for a given entity were not used in the original age model, for example because the dating sample was contaminated with organic material or because of age inversions. The dates excluded from the original age model are flagged in the database (date_used) but the other information on these dates is nevertheless included in the dating information table to ensure transparency.

The geochemical characteristics of the sample provide information that is required to assess the quality or reliability of these dates. The ratio of $^{230}$Th / $^{232}$Th, for example, is a measure of detrital thorium concentration in the sample and thus provides an initial quality control on each date. A $^{230}$Th / $^{232}$Th activity ratio > 300 is considered a good indicator of a reliable date (Hellstrom, 2006); a higher ratio indicates a cleaner sample with higher accuracy. The thorium corrected errors are also included to provide an indication
of the magnitude of the correction related to detrital thorium contamination.

2.2.5 Lamina dating information (table name: dating_lamina)

Variations in the drip-water geochemistry and/or quantity or cave conditions may occur at regular intervals, forming laminae of a range of thicknesses usually linked to surface seasonal climate variations (Fairchild and Baker, 2012). A high-resolution chronology can be established for such records by lamina counting, provided an absolute date is available for either the start or the end of the laminated sequence (e.g. be-sized with lamina counting, provided an absolute date is available for either the start or the end of the laminated sequence (e.g. because U/Th dates have been obtained or because the stalagmite was actively growing when collected). The identification of individual laminae can be difficult if they are very thin or of varying width, so best practice is to provide an estimate of the counting uncertainty that propagates from the absolute anchor dates. The lamina dating information table (Table S6) provides the age of each lamina in the sequence and the uncertainty on this dating; the absolute dates used as anchor points are given in the dating information table and identified in the date type field there as an event (see Sect. 2.2.4).

It should be noted that laminae can be formed on a variety of timescales, depending on the frequency that the thresholds for the formation of specific fabrics and mineralogies are crossed. Annual laminations are more likely in regions where there is a clear seasonality in climate or cave environment. In other regions, the lamination may be a result of lower- or higher-frequency variations in, for example, hydrologically effective precipitation (e.g. infiltrated waters) or soil CO2 production. It is imperative to demonstrate that the laminations are annual (see Table S9) before using lamina counting for dating.

2.2.6 Hiatus place mark information (table name: hiatus)

A prolonged cessation of speleothem growth can occur under unfavourable environmental conditions leading to, for example, undersaturation of drip water or cessation of dripping. Growth hiatuses can often be recognized from structural or mineralogical features, or inferred based on absolute dating. Growth hiatuses have to be taken into account in the construction of age models and thus the hiatus place mark table (Table S7) provides information on the location of such features. The hiatus is referenced to the specific depth at which it occurs, and this depth is considered as an imaginary sample that then appears with a specific sample_id in the sample table. There are some cases in which the hiatus depth was not recorded; in these cases the depth was specified as the imaginary mid-point depth between bracketing samples.

2.2.7 Gap place mark information (table name: gap)

When a composite record is created based on more than one individual speleothem from the same cave system, there may be discontinuities in the overlapping time of the individual records. These gaps are not growth hiatuses, but must be identified to facilitate plotting of the records. The gap place mark information table (Table S8) provides information on the location of sample gaps. The gap is referenced to the specific depth at which it occurs, and this depth is considered as an imaginary sample which then appears with a specific sample_id in the sample table. In composite records where sample depths are not given, the location of a gap can be derived from the sample ordering and the absence of isotopic information for a given sample. In point of fact, this table is empty in version 1 of the database.

2.2.8 Original chronology (table name: original_chronology)

The original chronology table (Table S9) provides an estimate of the age and age uncertainty, according to the original published age model for each sample on which stable isotope measurements have been made. The table also provides information on the type of age model (e.g. linear interpolation between dates, polynomial fit, Bayesian, StalAge; Scholz and Hoffmann, 2011, COPRA; Breitenbach et al., 2012, OxCal; Bronk Ramsey, 2001, 2008) used in the original publication. The fields ann_lam_check and dep_rate_check are included for quality assurance purposes, since they indicate that the assumption that laminae are truly annual has been explicitly tested.

2.2.9 Carbon isotope data (table name: d13C)

The carbon isotope data table (Table S10) contains the carbon isotope measurements. It also provides information on the laboratory precision of each measurement and the standard (PDB or Vienna-PDB) used as a reference.

2.2.10 Oxygen isotope data (table name: d18O)

The oxygen isotope data table (Table S11) contains the oxygen isotope measurements. It also provides information on the laboratory precision of each measurement and the standard (PDB or Vienna-PDB) used as a reference.

2.2.11 Publication information (table name: reference)

This table (Table S12) provides full bibliographic citations for the original references documenting the speleothems, their isotopic records and/or their age models. References on monitoring of the cave may also be provided. There may be multiple publications for a single speleothem record, and all of these references are listed. For convenience, there is also
There are several other factors that can affect ventilation, driven by advection of air or conduction through the bedrock.

To allow the user to assess whether cave temperatures are genuine, the distance of the speleothem from the cave entrance in order to be able to link this composite record to the individual speleothem records from which it was derived. Thus any single composite entity (composite_entity_id) is linked to multiple single entities (single_entity_id).

Multiple speleothem records showing a temporal overlap (and a similar signal) can be combined to create a composite record of changes through time. The composite record is treated as a distinct entity in the database. The link composite and entity information table (Table S14) is provided in order to be able to link this composite record to the individual speleothem records from which it was derived. Thus any single composite entity (composite_entity_id) is linked to multiple single entities (single_entity_id).

The notes table (Table S15) is provided in order to record additional information regarding the site which cannot be recorded in the fields of the table; this may also include entity specific information.

Individual records in the SISAL database were compiled either by the original authors or from published and open-access material by specialists in the collection and interpretation of speleothem records. In this latter case, the data compilers made every attempt to contact original authors to check that the compiled data were correct. The name of the person who compiled the data is included in the database (entity table, contact) so that they can be consulted in the future about queries or corrections. Individual records for the database were subsequently checked by a small number of regional coordinators, to ensure that records were being entered in a consistent way. Prior to entry in the database, the records were automatically checked using specially designed database scripts (in Python) to ensure that the entries to individual fields were in the format expected (e.g. text, decimal numeric, positive integers) or were selected from the pre-defined lists provided for specific fields. In defining both the formats and the pre-defined lists, the SISAL working group has taken special care to ensure that the entries are unambiguous. Null values for metadata fields were identified during the checking procedure, and checks were made with the data contributors whenever possible to ensure that null fields genuinely corresponded to missing information.

The database contains information designed to allow an assessment of the quality of an individual record. Thus, the entity metadata table contains information on, for example, the distance of the speleothem from the cave entrance in order to allow the user to assess whether cave temperatures are driven by advection of air or conduction through the bedrock. There are several other factors that can affect ventilation, for example the contrast between the cave and external climates, and cave morphology such as the size of the entrance or the number of entrances. Information on these factors is only rarely given in publications; we assume that this information would be more likely to be available if the original authors thought that ventilation was a significant influence on the speleothem record. Including information on distance from the cave entrance is therefore being regarded as a minimal indicator for record quality. Other fields that are included to allow the user to select appropriate records include geology, rock age, speleothem type and drip type.

The database also contains information to allow an assessment of the reliability of the dates used in constructing the original age model. The most important of these fields are those with information on the sample geochemistry (see Sect. 2.2.4), which allows the user to determine whether the samples were sufficiently large and sufficiently pure to yield good U/Th dates. The database also gives information on sample weight, which also addresses this issue. The information on the corrections employed, dating uncertainties and whether the original authors considered the date reliable (and therefore used it in constructing an age model) also provide insights into the reliability of individual chronologies.

The SISAL database is an ongoing effort and continuing efforts to update the records will include updating missing data fields for individual records. Analysis of the data is also useful for verification purposes and may result in corrections of some data. Any such changes to sites and entities included in version 1 of the database will be documented in subsequent updates. The SISAL working group also aims to provide new chronologies in future versions of the database based on Bayesian approaches, namely OxCal (Bronk Ramsey, 1995, 2008), COPRA (Breitenbach et al., 2012) and StalAge (Scholz and Hoffmann, 2011).

2.3 Quality control

2.4 Overview of contents

The first version of the SISAL database contains 211 022 $\delta^{18}O$ measurements, 127 115 $\delta^{13}C$ measurements from 371 speleothem records and 10 composites from 174 cave systems. This represents approximately 58 % of published speleothem records we have identified. Of the 371 speleothem records, 8 have been superseded, 7 provide information for which there are also updates or additional information recorded as separate entities, 6 have dating information but no isotopic records because the individual entities were only used to construct composite records, and 15 do not have age models. The database also contains 6 records that have not been published.

The distribution of sites is global in extent (Fig. 1). The majority (30 %) of the sites are from Europe (53 sites) and there is currently less good representation of sites from other regions. The temporal distribution of records is excellent for the past 2000 years (Fig. 2a) and good for the past 22 000 years (Fig. 2b). Altogether, 142 entities record some
Figure 1. Map of the location of sites in the database. Note that some sites include records for multiple individual speleothems, which are treated as separate entities in the database itself. The sites are coded with different shapes to indicate whether they provide records only for oxygen isotopes, or for both oxygen and carbon isotopes.

Figure 2. Plot showing the temporal coverage of individual entities in the database. Panel (a) shows records covering the past 2000 years (2 kyr BP), (b) shows records covering the past 22,000 years (22 kyr BP), and (c) shows records that cover the LIG (130–115 kyr BP).

part of the past 2000 years, 87 of which have a resolution \( \leq 10 \) years between samples on average. There are 253 entities recording some part of the past 22,000 years, including 153 with a resolution of \( \leq 100 \) years between samples on average. The database contains 42 entities from the last interglacial period (115,000 to 130,000 years before present), 41 of which have a resolution of \( \leq 1000 \) years between samples on average (Fig. 2c).

3 Data availability

The database is available in SQL and CSV format from https://doi.org/10.17864/1947.147 (Atsawawaranunt et al., 2018). The CSV format of the database is also available from https://www.ncdc.noaa.gov/paleo/study/24070 (last access: 4 September 2018).

4 Conclusions

The SISAL database is based on a community effort to compile isotopic measurements from speleothems to facilitate palaeoclimate analysis. Considerable effort has been made to ensure that there is adequate metadata and quality control information to allow the selection of records appropriate to answer specific questions and to document the uncertainties in the interpretation of these records. The database is publicly available.

The first version of the SISAL database contains 211,022 \( \delta^{18} \)O measurements and 127,115 \( \delta^{13} \)C measurements from 371 individual speleothem records, and 10 composites from 174 cave systems. The distribution of sites is global in extent. The temporal distribution is excellent for the past 2000 years and good for the past 22,000 years. There are also records that span the last interglacial period.

The format of the database is designed to facilitate the use of the data for regional- to continental-scale analyses,
and in particular to facilitate comparisons with and evaluation of isotope-enabled climate model simulations. The SISAL working group will continue to expand the coverage of the SISAL database and will provide new chronologies based on standardized age models; subsequent versions of the database will be made freely available to the community.

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