**Supplementary Information: The Lomagundi-Jatuli Event and Earth’s oxygenation**

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Methods

A total of 11,557 carbonate-carbon isotope data (d13Ccarb) were compiled for our study for the time interval 3.0–1.0 Ga (see Worksheets 1 and 2 in Data S1). A total of 3,386 carbonate-carbon isotope data were also compiled for Phanerozoic evaporite and related carbonate rocks and the modern open ocean (see Worksheet 3 in Data S1). Sources for isotope data and facies information are given in Tables S1 and S2 and keyed to the accompanying reference list. A total of 188 new d13Ccarb and oxygen isotope data were determined for carbonate rock samples for outcrops of the Tulomozero Formation at Raiguba (62°22.107’N, 033° 47.129’E) and Shunga (62°36.697’N, 034° 49.457’E) and from the Onega Parametric Hole (OPH) drill core spanning the transition from the Tulomozero Formation into the overlying Zaonega Formation; these data are reported in Table S5. Measurements were made on a Thermo Scientific Delta V Advantage continuous flow isotope ratio mass-spectrometer in the Department of Geology, University of Tartu, Estonia, following standard protocols. C and O data are reported in *per mil* (‰) deviation relative to the Vienna PeeDee Belemnite (V-PDB) and standard reproducibility was better than ±0.2‰.

Sample means were determined by the bootstrap method which enables estimation of the sampling bias on statistics (mean, median, etc.) by a resampling technique where a synthetic data set (bootstrap sample) is created by random independent sampling with replacement from an existing sample (population). The statistics of interest are estimated for each bootstrap sample whereby each step is repeated numerous times obtaining respective estimates that can be treated for additional statistical inferences (mean, standard deviation, confidence interval of the estimates, etc.). The bootstrapped means and confidence intervals reported in Table 1 (main paper) and Tables S3-S4 were calculated from 10,000 repetitions. The sample bias of the binned data was assessed further by jackknife estimates that were in all cases in agreement with bootstrapped means (jackknife bias = 0). Jackknife procedure is similar to the bootstrap method, but sampling is done without replacement and was developed for estimating the variance and bias of large data sets. During the jackknife procedure statistic estimate is calculated leaving out one observation at a time from the sample set. Similar to the bootstrap method, the statistic of an estimate for the bias can be calculated from the population of the repeated calculations.

C-O Isotope data

Our new (Table S5) and compiled published d13Ccarb data (Data S1) span the worldwide distribution of Palaeoproterozoic outcrop belts that contain the Lomagundi-Jatuli Event (LJE; Figure S1). Details of facies characterisation and interpretation were obtained from the publications given in the reference list. To evaluate the co-variation between C-isotope values and facies, the available published data for LJE-bearing successions worldwide were assigned to depositional settings where sufficient sedimentological details were available: (a) intertidal–sabkha; (b) nearshore marine–inner shelf and (c) open and deeper marine. The d13Ccarb data between 3.0 and 1.0 Ga (Data S1) were grouped in 100-Myr age bins (i.e. Geons).

A close up of a map

Description automatically generated

Figure S1. Generalised map of Palaeoproterozoic outcrop belts. Locations of Palaeoproterozoic successions utilised in this compilation shown by circled number. Tables S1and S2 list the sources for d13Ccarb data keyed to each locality. Data are reported in Worksheets 1 and 2 in Data S1.

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| Table S1. Sources of C isotope data for Palaeoproterozoic successions. | |
| Locality keyed to Figure S1 | Source (number keyed to references) |
| 1. Africa: Gabon | 2, 13, 58, 64 |
| 1. Africa: South Africa | 6, 12, 19, 22, 71 |
| 1. Africa: Zimbabwe | 41 |
| 1. Fennoscandian Shield: Imandra-Varzuga Belt | 32, 45, 52, 54 |
| 1. Fennoscandian Shield: Kalix Belt | 46, 79 |
| 1. Fennoscandian Shield: Onega Basin | 10, 32, 45, 47, 49, 51, 53, 54, 55 |
| 1. Fennoscandian Shield: Pechenga Belt | 32, 45, 50, 51, 54, 68, 69, 70 |
| 1. India: Aravalli Group | 39, 59, 66 |
| 1. Korea: Jiao-Liao-Ji Belt | 76 |
| 1. North America: Belcher Islands | 27, 31 |
| 1. North America: Lake Superior area | 5 |
| 1. North America: Labrador Trough | 48, 81 |
| 1. North America: Rae Craton | 42 |
| 1. North America: Wyoming area | 3, 4, 29, 30 |
| 1. North China: Hutuo Group | 72 |
| 1. Scotland: Loch Maree Group | 33 |
| 1. South America: Brazil | 39 |
| 1. Western Australia: Capricorn Orogen | 7, 18, 25, 35, 37, 40, 80 |

Table S1. Source of facies information used for Palaeoproterozoic successions. Information is keyed to each locality shown on Figure S1; source numbers are keyed to the numbered reference list. d13Ccarb data can be found in Worksheets 1 and 2 in Data S1.

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| Table S2. Sources of C-isotope data for Permian to Recent deposits. | |
| age of deposit | Source (numbers keyed to reference list) |
| Recent to modern | 9, 16, 21, 29, 34, 44, 60, 74 |
| Messinian | 8, 14, 20, 24, 26, 43, 56, 57, 63, 78 |
| Permian-Triassic | 1, 11, 15, 17, 23, 38, 61, 62, 65, 67, 73, 75, 77 |

Table S2. Sources of information used for Permian to Recent deposits; source numbers are keyed to the numbered reference list. d13Ccarb data can be found in Worksheet 3 in Data S1.

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| Table S3. Summary means of d13Ccarb (‰ V-PDB) data (C.I.–confidence interval) | | | | | | |
| data set | palaeoenvironmental setting | N | bootstrapped mean | bootstrapped mean 95% C.I. lower | bootstrapped mean 95% C.I. upper | jackknifed mean |
| Geons 26-24 | nearshore-inner shelf | 447 | 0.1 | -0.1 | 0.2 | 0.1 |
| open-deeper marine | 362 | -0.6 | -0.8 | -0.4 | -0.6 |
| Geon 23\_LJE | nearshore-inner shelf | 41 | 5.4 | 4.6 | 6.3 | 5.4 |
| open-deeper marine | 12 | -2.0 | -2.6 | -1.5 | -2.0 |
| Geon 22\_LJE | intertidal-sabkha | 85 | 9.8 | 8.6 | 11.1 | 9.8 |
| nearshore-inner shelf | 171 | 6.0 | 5.8 | 6.2 | 6.0 |
| open-deeper marine | 105 | 1.2 | 1.0 | 1.3 | 1.2 |
| Geon 21 LJE | intertidal-sabkha | 420 | 9.3 | 9.1 | 9.5 | 9.3 |
| nearshore-inner shelf | 275 | 5.7 | 5.5 | 6.0 | 5.7 |
| open-deeper marine | 518 | 2.0 | 1.9 | 2.2 | 2.0 |
| Geon 20 LJE | nearshore-inner shelf | 218 | 7.1 | 7.0 | 7.3 | 7.1 |
| open-deeper marine | 97 | 2.3 | 1.9 | 2.7 | 2.3 |
| Geons 20-19 | intertidal-sabkha | 140 | 0.6 | 0.4 | 0.9 | 0.6 |
| nearshore-inner shelf | 930 | 0.6 | 0.5 | 0.7 | 0.6 |
| open-deeper marine | 608 | -0.3 | -0.5 | -0.1 | -0.3 |
| Perm.-Trias. | intertidal-sabkha | 266 | 2.2 | 1.9 | 2.4 | 2.2 |
| open-deeper marine | 290 | 1.6 | 1.4 | 1.7 | 1.6 |
| Messinian | intertidal-sabkha | 518 | -2.3 | -2.6 | -2.0 | -2.3 |
| open-deeper marine | 440 | 0.8 | 0.7 | 0.8 | 0.8 |
| Recent | intertidal-sabkha | 125 | 2.6 | 2.3 | 2.9 | 2.6 |
| open-deeper marine | 1747 | 0.1 | 0.0 | 0.1 | 0.1 |

Table S3. Summary means keyed to palaeoenvironmental setting for each analysed time interval. d13Ccarb data can be found in Table S5 and Data S1. LJE-baring intervals highlighted in light red. Geons are 100 Myr.

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| Table S4. Summary means of d13Ccarb (‰ V-PDB) data for Geons 29-10 (C.I.–confidence interval). | | | | |
| Geon | bootstrapped mean | 95% C.I. lower | 95% C.I. upper | jackknifed mean |
| 29 | 1.4 | 1.5 | 1.2 | 1.4 |
| 28 | no data | | | |
| 27 | -0.3 | -0.6 | -0.1 | -0.3 |
| 26 | -0.3 | -0.6 | 0.0 | -0.3 |
| 25 | -0.5 | -0.6 | -0.4 | -0.5 |
| 24 | 0.2 | -0.2 | 0.6 | 0.0 |
| 23 | 4.0 | 3.5 | 4.6 | 4.0 |
| 22 | 4.7 | 4.4 | 5.1 | 4.7 |
| 21 | 4.8 | 4.4 | 5.1 | 4.8 |
| 20 | 2.0 | 1.8 | 2.2 | 2.0 |
| 19 | 0.0 | -0.1 | 0.1 | 0.0 |
| 18 | 0.5 | 0.4 | 0.6 | 0.5 |
| 17 | 1.4 | 0.7 | 2.2 | 1.4 |
| 16 | -0.7 | -0.8 | -0.7 | -0.7 |
| 15 | -0.3 | -0.3 | -0.2 | -0.3 |
| 14 | -0.4 | -0.5 | -0.3 | -0.4 |
| 13 | -0.3 | -0.5 | -0.0 | -0.3 |
| 12 | 2.2 | 2.0 | 2.3 | 2.2 |
| 11 | 0.3 | 0.1 | 0.4 | 0.3 |
| 10 | 1.4 | 1.2 | 1.6 | 1.4 |
|  | | | | |
| Summary means of d13Ccarb (‰ V-PDB) data for grouped Geons | | | | |
| pre-LJE Geons 29-24 | -0.1 | -0.2 | 0.0 | -0.1 |
| LJE Geons 23-20 | 4.0 | 3.9 | 4.1 | 4.0 |
| post-LJE Geons 19-10 | 0.0 | 0.1 | 0.0 | 0.0 |

Table S4. Summary means for d13Ccarb values (‰ V-PDB) calculated for individual Geons spanning 3.0–1.0 Ga. d13Ccarb data can be found in Table S5 and Worksheets 1 and in Data S1. LJE-bearing intervals highlighted in light red. Geons are 100 Myr.

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| Table S5. C-O isotope data for upper Tulomozero and lower Zaonega Fms, Onega Basin, Russia. | | | | | | | |
| OPH core depth (m) | δ13Ccarb ‰ (V-PDB) | δ18O ‰ (V-PDB) | |  | Tulomozero Fm outcrop | δ13Ccarb ‰ (V-PDB) | δ18O ‰ (V-PDB) |
| 1888.7 | -3.7 | -9.8 |  | | RG01(base sect.) | 10.6 | -9.3 |
| 1888.8 | -0.4 | -7.2 |  | | RG02 | 9.8 | -6.6 |
| 1888.88 | 0.3 | -7.6 |  | | RG03 | 9.5 | -9.6 |
| 1888.9 | 0.3 | -7.6 |  | | RG04 | 9.9 | -10.0 |
| 1888.9 | -0.6 | -8.0 |  | | RG05 | 9.7 | -8.6 |
| 1889.2 | -0.4 | -11.8 |  | | RG06 | 9.6 | -7.7 |
| 1902.7 | 1.6 | -11.3 |  | | RG07 | 8.2 | -9.0 |
| 1902.8 | 0.7 | -11.7 |  | | RG08 | 8.5 | -7.1 |
| 1903.0 | 1.3 | -12.5 |  | | RG09 | 7.8 | -10.5 |
| 1903.2 | 1.1 | -12.1 |  | | RG10 | 8.7 | -8.0 |
| 1903.3 | 2.3 | -11.6 |  | | RG11 | 10.3 | -8.1 |
| 1903.9 | 1.7 | -13.2 |  | | RG12 | 11.0 | -8.7 |
| 1904.0 | 1.5 | -13.8 |  | | RG13 | 8.1 | -8.7 |
| 1904.16 | 1.8 | -12.4 |  | | RG14 | 8.4 | -9.3 |
| 1904.2 | 1.9 | -12.4 |  | | RG16 | 6.9 | -10.5 |
| 1904.2 | 1.8 | -12.4 |  | | RG16B | 6.7 | -11.5 |
| 1905.3 | 2.0 | -12.7 |  | | RG17 (top sect.) | 7.6 | -10.1 |
| 1905.7 | 2.2 | -14.0 |  | |  |  |  |
| 1905.7 | 2.0 | -12.8 |  | | SN01 (base sect.) | 8.4 | -11.7 |
| 1915.1 | 4.3 | -12.9 |  | | SN02 | 8.7 | -8.1 |
| 1915.6 | 4.2 | -13.2 |  | | SN03 | 9.7 | -12.4 |
| 1915.8 | 5.2 | -11.8 |  | | SN04 | 9.6 | -11.6 |
| 1926.0 | 5.0 | -13.7 |  | | SN05 | 9.4 | -11.6 |
| 1926.2 | 4.7 | -13.6 |  | | SN06 | 8.9 | -11.5 |
| 1926.23 | 4.7 | -13.6 |  | | SN07 | 8.9 | -10.3 |
| 1926.5 | 5.1 | -12.8 |  | | SN09 | 8.1 | -9.4 |
| 1926.9 | 4.5 | -13.1 |  | | SN10 | 7.0 | -5.9 |
| 1926.93 | 4.5 | -13.1 |  | | SN11 | 9.1 | -10.0 |
| 1927.4 | 4.9 | -13.7 |  | | SN12 | 8.8 | -7.7 |
| 1927.8 | 5.0 | -12.5 |  | | SN13 | 8.9 | -5.1 |
| 1935.6 | 5.2 | -11.0 |  | | SN14 | 7.7 | -5.2 |
| 1946.2 | 4.8 | -12.7 |  | | SN15 | 8.1 | -7.0 |
| 1946.2 | 4.8 | -12.7 |  | | SN16 | 8.6 | -8.4 |
| 1946.6 | 4.5 | -13.9 |  | | SN17 | 8.5 | -9.2 |
| 1946.9 | 4.5 | -13.5 |  | | SN18 | 7.5 | -5.3 |
| 1947.3 | 3.2 | -14.8 |  | | SN19 | 8.9 | -9.0 |
| 1947.7 | 4.1 | -14.5 |  | | SN20 | 8.9 | -9.9 |
| 1957.2 | 4.3 | -13.5 |  | | SN21 | 9.0 | -11.2 |
| 1958.1 | 5.1 | -10.8 |  | | SN22 | 8.3 | -5.8 |
| 1958.8 | 4.2 | -13.1 |  | | SN23 | 7.5 | -5.1 |
| 1958.09 | 5.1 | -10.8 |  | | SN24 | 8.5 | -8.1 |
| 1969.9 | 3.5 | -14.4 |  | | SN25 | 8.6 | -10.6 |
| 1970.4 | 5.4 | -12.9 |  | | SN26 | 9.7 | -12.9 |
| 1970.41 | 5.4 | -12.9 |  | | SN27 | 9.6 | -12.5 |
| 1972.0 | 5.8 | -12.3 |  | | SN28 | 9.0 | -13.3 |
| 1972.3 | 3.7 | -12.5 |  | | SN29 | 9.2 | -12.3 |
| 1972.31 | 3.7 | -12.5 |  | | SN30 (top sect.) | 8.6 | -12.3 |
| 1972.8 | 6.3 | -12.7 |  | |  |  |  |
| 1980.3 | 6.2 | -13.3 |  | |  |  |  |
| 1980.8 | 7.8 | -12.8 |  | |  |  |  |
| 1980.9 | 7.3 | -13.1 |  | |  |  |  |
| 1991.7 | 8.2 | -12.8 |  | |  |  |  |
| 1992.3 | 8.1 | -12.7 |  | |  |  |  |
| 1992.3 | 7.5 | -12.9 |  | |  |  |  |
| 1992.8 | 8.4 | -12.6 |  | |  |  |  |
| 1992.83 | 8.4 | -12.6 |  | |  |  |  |
| 2003.1 | 8.1 | -13.3 |  | |  |  |  |
| 2003.1 | 8.8 | -12.8 |  | |  |  |  |
| 2003.06 | 8.1 | -13.3 |  | |  |  |  |
| 2003.09 | 8.8 | -12.8 |  | |  |  |  |
| 2004.0 | 8.8 | -13.5 |  | |  |  |  |
| 2004.66 | 8.7 | -13.5 |  | |  |  |  |
| 2004.69 | 8.8 | -13.5 |  | |  |  |  |
| 2004.7 | 8.7 | -13.5 |  | |  |  |  |
| 2004.7 | 8.8 | -13.5 |  | |  |  |  |
| 2005.9 | 8.4 | -13.6 |  | |  |  |  |
| 2006.0 | 8.9 | -13.3 |  | |  |  |  |
| 2010.5 | 7.9 | -13.7 |  | |  |  |  |
| 2011.08 | 7.9 | -13.6 |  | |  |  |  |
| 2011.1 | 7.9 | -13.6 |  | |  |  |  |
| 2011.7 | 7.8 | -13.6 |  | |  |  |  |
| 2019.2 | 7.7 | -13.4 |  | |  |  |  |
| 2019.21 | 7.7 | -13.4 |  | |  |  |  |
| 2025.3 | 5.3 | -13.9 |  | |  |  |  |
| 2035.7 | 6.3 | -8.8 |  | |  |  |  |
| 2035.71 | 6.3 | -8.8 |  | |  |  |  |
| 2036.4 | 5.4 | -12.0 |  | |  |  |  |
| 2036.42 | 5.4 | -12.0 |  | |  |  |  |
| 2037.6 | 6.1 | -10.8 |  | |  |  |  |
| 2037.9 | 5.3 | -12.1 |  | |  |  |  |
| 2038.4 | 5.4 | -12.2 |  | |  |  |  |
| 2043.6 | 5.9 | -10.6 |  | |  |  |  |
| 2043.7 | 5.0 | -12.3 |  | |  |  |  |
| 2044.0 | 5.3 | -12.5 |  | |  |  |  |
| 2044.3 | 5.2 | -12.5 |  | |  |  |  |
| 2044.3 | 5.2 | -12.5 |  | |  |  |  |
| 2044.5 | 4.9 | -11.9 |  | |  |  |  |
| 2049.1 | 5.0 | -12.1 |  | |  |  |  |
| 2050.7 | 4.9 | -12.8 |  | |  |  |  |
| 2050.8 | 4.5 | -12.9 |  | |  |  |  |
| 2051.6 | 4.5 | -12.6 |  | |  |  |  |
| 2052.28 | 4.6 | -12.4 |  | |  |  |  |
| 2052.3 | 4.6 | -12.4 |  | |  |  |  |
| 2052.3 | 4.7 | -12.4 |  | |  |  |  |
| 2052.34 | 4.7 | -12.4 |  | |  |  |  |
| 2052.5 | 4.1 | -13.5 |  | |  |  |  |
| 2052.6 | 5.2 | -13.4 |  | |  |  |  |
| 2058.47 | 5.8 | -8.2 |  | |  |  |  |
| 2058.5 | 5.8 | -8.2 |  | |  |  |  |
| 2067.9 | 4.0 | -12.9 |  | |  |  |  |
| 2068.0 | 6.5 | -12.2 |  | |  |  |  |
| 2068.05 | 3.4 | -12.5 |  | |  |  |  |
| 2068.1 | 3.4 | -12.5 |  | |  |  |  |
| 2076.6 | 3.9 | -13.3 |  | |  |  |  |
| 2076.7 | 0.8 | -14.4 |  | |  |  |  |
| 2077.0 | 3.8 | -13.3 |  | |  |  |  |
| 2077.1 | 4.3 | -12.9 |  | |  |  |  |
| 2077.37 | 3.9 | -12.7 |  | |  |  |  |
| 2077.4 | 3.9 | -12.7 |  | |  |  |  |
| 2077.6 | 5.1 | -12.1 |  | |  |  |  |
| 2078 | 4.5 | -11.2 |  | |  |  |  |
| 2078.0 | 4.5 | -11.2 |  | |  |  |  |
| 2084.7 | 4.0 | -14.4 |  | |  |  |  |
| 2084.8 | 5.6 | -13.0 |  | |  |  |  |
| 2086.4 | 5.6 | -12.1 |  | |  |  |  |
| 2086.4 | 5.6 | -12.1 |  | |  |  |  |
| 2093.1 | 6.4 | -11.4 |  | |  |  |  |
| 2093.12 | 6.4 | -11.4 |  | |  |  |  |
| 2094.2 | 5.7 | -12.2 |  | |  |  |  |
| 2102.8 | 6.5 | -11.3 |  | |  |  |  |
| 2102.9 | 6.6 | -11.4 |  | |  |  |  |
| 2103.0 | 4.6 | -12.9 |  | |  |  |  |
| 2103.6 | 5.6 | -12.6 |  | |  |  |  |
| 2104.5 | 7.4 | -10.5 |  | |  |  |  |
| 2117.6 | 7.3 | -10.6 |  | |  |  |  |
| 2117.6 | 7.3 | -10.7 |  | |  |  |  |
| 2117.64 | 7.3 | -10.7 |  | |  |  |  |
| 2118.2 | 7.4 | -10.5 |  | |  |  |  |
| 2118.46 | 7.6 | -10.7 |  | |  |  |  |
| 2118.5 | 7.6 | -10.7 |  | |  |  |  |
| 2119.09 | 7.8 | -10.6 |  | |  |  |  |
| 2119.1 | 7.8 | -10.6 |  | |  |  |  |
| 2205.4 | 12.2 | -7.6 |  | |  |  |  |
| 2206.2 | 11.7 | -4.6 |  | |  |  |  |
| 2208.1 | 12.2 | -3.6 |  | |  |  |  |
| 2208.8 | 12.5 | -2.9 |  | |  |  |  |
| 2252.1 | 11.4 | -10.4 |  | |  |  |  |
| 2290.4 | 9.7 | -9.0 |  | |  |  |  |
| 2305.3 | 9.2 | -7.0 |  | |  |  |  |
| 2314.5 | 9.9 | -9.1 |  | |  |  |  |
| 2324.4 | 8.6 | -9.0 |  | |  |  |  |
| 2328.4 | 8.1 | -7.2 |  | |  |  |  |

Table S5. Carbonate C and O isotope data (N=188) from the LJE-bearing succession n the Onega Basin, NW Russia. Data are from samples of the Tulomozero Formation at Raiguba (RG: 62°22.107’N, 033° 47.129’E) and Shunga (SN: 62°36.697’N, 034° 49.457’E) and from the portion of the Onega Parametric Hole (OPH) drill core that recovers the upper part of the Tulomozero Formation and lower part of the overlying Zaonega Formation.

Data S1 (separate file)

Dataset for d13Ccarb values from 3.0–1.0 Ga and for Permian–Recent deposits. This file contains three worksheets. Worksheets 1 and 2 consist of published d13Ccarb data spanning from 3.0­–1.0 Ga compiled from Refs. 80 and 81 and from publications that postdate those workers’ compilations (as listed in Table S1). In compiling the updated dataset for 3.0–1.0 Ga, we excluded carbonate rocks associated with banded-iron formation and those from features of clear diagenetic origin (e.g. cements, concretions). Worksheet 3 contains published d13Ccarb values compiled for marine and evaporite settings of Permian-Triassic, Messinian and Recent settings; sources of these data are listed in Table S2.

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