Supplementary Material

**O, C methodology**

The isotopic analysis was carried out at the Department of Geosciences of the University of Padova on 200–300 mg of sample powder, which was reacted with pure H3PO4 (≥99.0%) in a borosilicate glass vial at 70 °C for ca. 3 h in a GasBench II instrument connected to the continuous flow system of a DELTA V Advantage mass spectrometer (Thermo Scientific). The raw δ13C and δ18O values were normalized by the values from the lab internal standard Maq1, which is a Carrara marble (δ13C =2.58‰; δ18O=−1.15‰ V-PDB) periodically calibrated against the international standard NBS 19 (Coplen et al., 2006).

**S methodology**

The isotopic analyses for S measurement were carried out from the same micritic samples used for O and C analyses. The detailed description of methodology is described in He et al. (2020)

**Sr, Pb and Zn methodology**

A few tens of mg of powdered carbonate material were leached in 2.2 M high purity acetic acid during 1 to 2 hours at room temperature in conical shaped 2 ml vials. The solutions were centrifuged and the supernatant was recovered and transferred to Teflon vials, where it was dried down on a hot plate. The residue was redissolved in a few drops of 14 M HNO3 and dried down again, before Sr, Pb and Zn separation from the matrix using two distinct aliquots of the dissolved sample.

*Strontium and lead*

Separation of Sr and Pb was carried out using a Sr-Spec resin. The Sr and Pb separates were redissolved in 5 ml of ~2% HNO3 solutions and ratios (200 cycles for Sr and 150 cycles for Pb, of 8 seconds each) were measured using a Thermo Neptune PLUS Multi-Collector ICP-MS in static mode.

The 88Sr/86Sr (8.375209) ratio was used to monitor and correct instrumental mass fractionation during the run. Interferences at masses 84 (84Kr), 86 (86Kr) and 87 (87Rb) were also corrected in-run by monitoring 83Kr and 85Rb. The SRM987 standard was used to check external reproducibility, which on the long-term (more than 100 measurements during one year) was 10 ppm. The internally corrected 87Sr/86Sr values were further corrected for external fractionation (due to a systematic difference between measured and a nominal standard ratio of the SRM987 of 87Sr/86Sr = 0.710248: MacArthur et al., 2001) by a value of -0.021‰ per amu. Total procedural blanks were < 100 pg Sr which are insignificant compared to the amounts of Sr purified from the whole rock samples.

For Pb, instrumental mass fractionation was corrected in-run using 203Tl/205Tl **=** 0.418922 and the 204Hg interference on 204Pb was corrected by monitoring 202Hg. The SRM981 standard was used to check the long-term external reproducibility of measures which is 0.0079% for 206Pb/204Pb, 0.0070% for 207Pb/204Pb, 0.0093% for 208Pb/204Pb, 0.0059 for 208Pb/206Pb, 0.0057% for 207Pb/206Pb, and 0.0041% for 208Pb/207Pb. The in-run corrected Pb isotope ratios were further corrected for external fractionation (due to a systematic difference between measured and accepted ratios of SRM981) by a value of +0.36‰ amu using the SRM981 values proposed by Baker et al. (2004).

Of the analysed samples only 6 contained enough Pb to be measured reliably. Procedural blanks were <200 pg, which does not affect the isotope ratios in the samples retained.

*Zinc*

To separate Zn from the carbonate rocks leached as described above we used the protocol of Maréchal et al. (1999) as subsequently modified by Chen et al. (2009, 2015). Before measurement of isotope ratios using a Thermo Neptune PLUS multicollector ICP-MS in static mode at the Univeristy of Geneva, the purified Zn solutions were mixed with a SRM976 Cu standard solution for in-run fractionation correction of Zn isotope ratios using 65Cu/63Cu = 0.4456 (Maréchal et al., 1999). The sample introduction system consists of a tandem quartz glass spray chamber coupled with a medium flow PFA nebulizer (100-120 μl/min). Plasma Ar gas flows were 15 l/min for coolant gas, 1 l/min for the nebulizer gas and 0.7 l/min for the auxiliary gas. An RF generator with power of 1200 W supplied the ICP. The used Faraday Cup configuration allows simultaneous collection of the four Zn masses (64, 66, 67 and 68 on Faraday cups L1, H1, H2 and H3 respectively), the two Cu masses (63 and 65 on Faraday cups L2 and C respectively) and mass 62 (on Faraday cup L3) to correct for Ni interferences. Nickel produces an important interference in Cu and Zn measurements at mass 64, which is corrected by measuring 62Ni and using the 64Ni/62Ni known constant ratio (0.25497).

After instrument warm-up and setting, sequences were run automatically using a Cetac autosampler. A blank and a standard were run before and after each unknown sample and δ66Zn values were calculated with the standard bracketing method (after blank correction) using 66Zn/64Zn ratios that were corrected in run for instrumental mass fractionation using 65Cu/63Cu = 0.4456 of the SRM976 standard (Maréchal et al., 1999) added to the Zn sample solution. Between each measurement (sample or standards), the machine was rinsed with 2% HNO3 and suprapure H2O from two different vials during 3 and half minutes. Blank measurements consisted of 1 block of 20 cycles (8s each) and sample and standard measurements consisted of 1 block of 50 to 80 cycles and 8s integration time per measure.

In order to ensure 100% recovery of Zn during chromatography (e.g., Maréchal et al., 1999; Maréchal and Albarède, 2002) elution tests were performed using both standard Zn solutions and dissolved rock standards. In both cases elution curves were identical and conformed with the reagent amounts proposed by Maréchal et al. (1999). Recovery based on the elution curves is estimated to be near to 100%.

Polyatomic interferences, especially from Ti and Na combining with O, H, Ar (Mason et al., 2004) can affect Zn isotope measurements both by interfering directly with Zn isotope masses and indirectly with Cu isotope masses that are used for in run instrumental fractionation correction. For this reason, every sample before being run was monitored for the presence of the “unwanted” elements above. It was found that these elements occurred in tiny amounts (48Ti, the most abundant Ti isotope at 73.6% was always <3 mV and 23Na was <30 mV). Additionally, samples were monitored at the masses 63 and 65 in order to see whether the above elements did form polyatomic species at these masses (e.g., 47Ti16O, 46Ti16O1H, 23Na40Ar, 49Ti16O, 48Ti16O1H) but the intensities were below the background noise at these masses indicating that although occurring in the solutions in tiny amounts these elements were not forming enough polyatomic species to be detected with Faraday cups.

Each sample fraction was run 2 to 3 times and the reported values are averages of these runs with associated 2SD uncertainties (Tables 1-3).

The overall accuracy of the method (chromatographic separation, isotope ratio measurement) is confirmed by the isotope values obtained on the rock standards BHVO-2, AGV-1, and JA-2 (0.30±0.07, 0.30±0.08, 0.26±0.03 respectively), which agree with those reported by Chen et al. (2015) (0.31±0.03, 0.29±0.03, 0.28±0.03) (Table S2).

The long-term reproducibility of the method based on the measurement of standard solutions (Zn Baker ICP-MS solution) is 0.04‰ (2SD) on δ66Zn.