Paired analyses of oxygen isotopes and elemental ratios within individual shells of benthic foraminifera genus *Uvigerina.*

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Abstract

We compare different methodologies (*in situ* and bulk) for obtaining $\delta^{18}O$ and elemental ratios in the benthic foraminifera genus *Uvigerina* from ODP Site 1015, (California Margin), to assess what new information can be obtained with high-resolution *in situ* techniques. Specimens were prepared in epoxy mounts and exposed in cross-section such that multiple high-resolution analyses could be completed on the same shells using both Secondary Ionization Mass Spectrometry (SIMS) and Laser Ablation Inductively Coupled Mass Spectrometry (LA-ICP-MS). We also obtained elemental ratio data using LA-ICP-MS depth-profile measurements on whole, uncast foraminifera and elemental ratio and oxygen isotopes with standard bulk techniques using the same species of benthic foraminifera from the same sediment sub-samples. Comparison of the data collected by the different methodologies indicates that there is a consistent offset of ~ 0.9± 0.1‰ between SIMS and bulk analysis of $\delta^{18}O$. The *in situ* laser data studied in epoxy mount is correlated with the foraminifera bulk measurements for both Mg and Sr, whereas the *in situ* depth-profile laser measurements of Mg and Sr from whole foraminifera are less correlated with the bulk measurements. We also observe that the intra-shell variability for each of the proxies is larger than the analytical error and does not follow chamber number. We propose that the $\delta^{18}O$, Mg, and Sr variability within and between single specimens at this site is linked to some combination of measurement bias, vital effects, and variable environmental conditions in the pore water where the tests were precipitated. This information can in turn be related to the regional setting of the site.

Keywords: Elemental ratios; LA-ICPMS; ICP-MS; Oxygen isotopes; SIMS; Paired in situ analysis; Standard bulk techniques; Benthic foraminifera *Uvigerina*.

1. Introduction

The isotopic and elemental compositions of calcium carbonate tests (shells) of fossil foraminifera are widely used to infer past ocean chemistry and temperature (e.g., Nürnberg et al., 1996; Shackleton et al., 1984; Rosenthal et al., 1997; Lear et al., 2000; Wejnert et al., 2013; Mekik, 2018 and reference there-in). As recently as two decades ago, geochemical analysis of foraminiferal calcite was generally restricted to bulk sampling methods (i.e. data obtained on an multiple tests combined into one sample). Since then, however, techniques for multi-element analysis of small sample volumes have been developed on sector field inductively coupled plasma mass spectrometry (ICP-MS) (Rosenthal et al., 1997; Marchitto, 2006) and quadrupole ICP-MS (Yu et al., 2005; Harding et al., 2006). Over the last decade, high-resolution analytical methods for measuring both Mg/Ca and $\delta^{18}O$ have advanced such that micron-scale *in situ* analyses are now feasible by secondary ion mass spectrometry (SIMS) (Wycech et al., 2018a and reference there-in) and laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) (Fehrenbacher, et al., 2015 and reference there-in). These technical advances allowed researchers to better understand empirical calibrations of element/Ca ratios used as proxies for paleo-environmental reconstruction (Nürnberg, 1995; Nürnberg et al., 1996; Eggins et al., 2003, 2004; Sadekov, 2005; Toyofoko and Kitazato, 2005; Pena et al., 2008; Groeneveld and Filipsson, 2013). They have also been used to assess post depositional alteration (Kozdon et al., 2013; Wycech et al., 2018b), and to resolve short time scale (seasonal or decadal) environmental data for paleo-reconstructions (Ford et al., 2015), or for considering biomineralization processes (Branson et al., 2016).

Microanalytical methods such as SIMS and LA-ICP-MS are particularly useful when a limited number of specimens are available or when an assessment of chemical heterogeneity is required (Glock et al., 2012, and references therein). One clear advantage of micro-analytical *in situ* techniques over bulk analyses is that single foraminiferal tests can be re-analyzed multiple times by the same or different *in situ* techniques. As a result, it is technically feasible to integrate a diverse range of analytical approaches to better characterize the environmental signals recorded in single foraminiferal shells or to refine understanding of biomineralization or post deposition alteration processes. For example, laser ablation techniques on single foraminifera have been used to determine quantitative element/Ca ratios from depth-profiling analysis of single, whole specimens (Wu and Hillaire-Marcel, 1995; Hathorne et al., 2003; Reichart et al., 2003; Pena, et al., 2005; Munsel et al., 2010; Fehrenbacher et al., 2017). SIMS and electron probe micro-analysis (EPMA) have been used to produce elemental maps, determine elemental ratios, and (for SIMS only) test novel isotopic proxies in foraminiferal calcite (Allison and Austin, 2003; Sano et al., 2005; Bice et al., 2005; Kunioka et al., 2006; Rollion-Bard and Erez, 2010; Glock et al., 2012; Vigier et al., 2015. Kozdon et al., 2013; 2009, Evans et al., 2015). More recently, SIMS methods have been further developed to permit analysis of planktonic foraminifera $\delta^{18}O$ (Kozdon et al., 2009; 2011; 2013; Vetter et al., 2015; Wycech et al., 2018a and b). Just one study, however, has analyzed intra-shell $\delta^{18}O$ variability in benthic foraminifera (Rollion Bard et al., 2008). Rollion-Bard et al. (2008) analyzed $\delta^{18}O$ by SIMS in specimens of the benthic genus *Amphistegina.* They report that the thin layers of calcite that have elevated Mg/Ca and are associated with "primary calcite" precipitated within an organic matrix of newly deposited chamber have markedly (~3‰) lower $\delta^{18}O$ values than the "secondary" calcite that comprises 95% of the shell. They argue that the lower $\delta^{18}O$ of primary calcite is due to some ''vital effect" that lowers the $\delta^{18}O$ of bulk analyses below the value predicted by inorganic experiments (e.g. Kim and O'Neil, 1997).

Given that the $\delta^{18}O$ of benthic foraminifera is a foundational global-scale paleoclimate proxy (Lisiecki and Raymo, 2005), further interrogation of benthic foraminifera is warranted. In this study, we leveraged updated SIMS methods developed over the last decade along with element/Ca analysis by LA-ICP-MS to evaluate two generalized hypotheses that emerge from the work of Rollion-Bard et al. (2008): 1) that at intra-shell resolution, Mg/Ca variability anticorrelates with $\delta^{18}O$, and 2) that at micron-scale, $\delta^{18}O$ anticorrelates with indicators of organic matrix. We investigated samples from ODP Site 1015 in the Santa Monica Basin representing two-time slices, the last 1000 years and the Younger Dryas (YD; 12.9–11.7 ky BP) (Rasmussen et al., 2006) focusing on the benthic genus *Uvigerina,* specifically *Uvigerina peregrina*, with ornamentation which is common to the California margin (Okhushi et al., 2013; Davis et al., 2016; Balestra et al., 2018). The Santa Monica basin has been targeted as a region for paleoceanographic reconstructions because its location strategically links it to mechanisms of regional climate oscillations and ecosystem changes in the California Margin (Balestra et al., 2018). We measured both the Mg/Ca ratio (LA-ICP-MS) and $\delta^{18}O$ (SIMS) on single foraminifera tests that were embedded in an epoxy mount and exposed in cross-section. For comparison, we collected element/Ca ratio data with LA-ICP-MS measurements on whole uncast foraminifera, as well as element/Ca ratios and $\delta^{18}O$ values by standard bulk techniques for each time slice using the same foraminifera species (i.e. *Uvigerina*) from the same sediment samples. We ultimately aim to assess the utility of analyzing single-shells using paired, high spatial-resolution geochemical analyses in single *Uvigerina*, which is a benthic genus commonly used for paleoclimate studies.

2. Material and Methods

2.1 ODP Site 1015 and *Uvigerina* spp.

ODP Site 1015, (33°42.925'N, 118°49.185'W, water depth 901 m; Figure 1) was drilled in the deepest part of Santa Monica Basin (Shipboard Scientific Party, 1997). Two holes were drilled at this site (A = 149.5 m and B = 98.7 m core lengths, Shipboard Scientific Party, 1997). In this study, sediment samples for analyses of the benthic foraminifera *Uvigerina* spp. were selected to avoid turbidite intervals (Romans et al., 2009). The age model for this core and thus the age of the samples utilized is based on Balestra et al. (2018) (Table 1). The average sedimentation rate for the late Holocene (0-11.7 ka) at this site is 2.0 mm/yr. For the Last Glacial Maximum (LGM) and deglacial period (22-11.7 ka) it is 3.6 mm/yr. Using this age model, two time-periods were chosen for this study, the last 1 ky of sediment accumulation and sediments deposited during the Younger Dryas (YD; 12.9- 11.7 kyr B.P) (Rasmussen et al., 2006). The last 1 ky samples represent the "warm" interglacial period, while the YD is a period during the last deglaciation when Northern Hemisphere climate returned abruptly to near-glacial conditions (i.e. cold, dry and windy) for ~1.5 ky (Fairbanks, 1989; Bond et al., 1997).

The benthic foraminifera *Uvigerina* spp. selected for analysis is present in both time-slices and it is relatively insensitive to changes in carbonate ion concentrations ($\Delta[CO_3^{2-}]$) (Elderfield et al., 2010). This genus is commonly found in mesotrophic environments, often characterized by fine-grained sediments with elevated organic matter content (Van der Zwaan et al., 1986). *Uvigerina* spp. lives in shallow infaunal depth habitats (Van der Zwaan et al., 1986; Fontanier et al., 2002; Schweizer et al., 2005). The weaker sensitivity to carbonate ion changes of this genus when compared to epifaunal species (Elderfield et al., 2006; 2010), is probably because it calcifies from pore water at 1-2 cm depth within the sediment, where $\Delta[CO_3^{2-}]$ tends to be close to zero (Tachikawa and Elderfield, 2002; Martin and Saylaes, 1996; Elderfield et al., 2010). Therefore, there is limited influence of $\Delta[CO_3^{2-}]$ on shell Mg/Ca of this genus (Elderfield et al., 2010).

2.2. SIMS measurements of δ^{18}O and OH/O

For SIMS analysis, six sediment samples representing the selected time intervals were soaked overnight in deionized water (pH= ~8.0, buffered), washed over 63 µm and 250 µm sieves, and oven dried at 45°C (as by Kozdon et al., 2013). The >250 µm fraction was then examined for benthic foraminifera (i.e., *Uvigerina* spp.). Sample cleaning consisted of multiple ultrasonication steps in MilliQ water and methanol, with additional rinses in MilliQ water between and after sonication. The cleaned tests were embedded along with two grains of UWC-3 calcite standard (δ^{18}O=12.49‰ Vienna Standard Mean Ocean Water, VSW; Kozdon et al., 2009) in a single 25-mm diameter, round epoxy mount. This mount was made with Buehler EpoxiCure® 2 hardener and resin (before the product formulation changed in 2016). After embedding, the epoxy mount was ground to the level of best sample exposure (Kozdon et al., 2011; 2013) and polished to a topographic relief of less than 1 µm (Kita et al., 2009). The sample mounts were gold-coated for scanning electron microscope (SEM) imaging and SIMS analyses. Since the genus *Uvigerina* adds a new layer of calcite to all existing chambers every time that a new chamber is formed (Grunlund and Hansen, 1976) we acquired high-resolution SEM images of all samples before SIMS analysis to facilitate targeting appropriate calcite layers. SEM images were taken after the *in situ* measurements to record the relative spot positions (Figure 2 and 3, right panels).

In situ δ^{18}O data were acquired from the *Uvigerina* spp. test walls at the WiscSIMS Laboratory (University of Wisconsin-Madison) with a CAMECA IMS 1280 large-radius multi-collector SIMS (Kita et al., 2009; Valley and Kita, 2009). Analytical conditions on the SIMS are like those reported for the 10-µm spot analyses by Kozdon et al. (2013). A $^{133}Cs^{+}$ primary ion beam with an intensity of ~1.3 nA was focused to a beam-diameter of ~10 µm. The typical secondary $^{16}O^{-}$ intensity was 2.5 × 10^{9} counts per second (cps), and $^{18}O^{-}$, $^{16}O^{1}H^{-}$, and $^{16}O^{-}$ ions were simultaneously recorded by three Faraday cup detectors. Charging of the sample surface was compensated by gold coating and by an electron flood gun focused on the analysis site. Four to six consecutive measurements of UWC-3 calcite standard were performed before and after every set of 5–16 sample analyses. The precision (spot-to-spot reproducibility) for each sample analysis is calculated as the 2 s.d. of the bracketing UWC-3 analyses. Across the entire session, the average spot-to-spot reproducibility (1 s.d.) of δ^{18}O analyses in the UWC-3 standard was ±0.15‰.

Between three and seven 10-μm spots were analyzed for $\delta^{18}O$ on each of 38 tests (16 tests from <1 ky and 22 tests from the YD, for a total of 144 10-μm spots). The ratio $^{16}OH^{-}/^{16}O^{-}$ (OH/O, hereafter) was measured simultaneously during all $\delta^{18}O$ analyses. The average OH/O of bracketing UWC-3 standard measurements (an anhydrous marble) was used to measure "background" $^{16}OH^{-}$, which was subtracted from each sample analysis in the intervening block to calculate "background-corrected" OH/O (Wycech et al., 2018a and b). Following SIMS analysis, data were screened for outliers in secondary ion yield and background-corrected OH/O, and pit morphologies were examined by SEM for irregularities. Following these quality control measures, out of a total of 144 SIMS spots measured in the calcite tests just 1 was removed from interpretation. An additional 39 SIMS spots were removed from our paired-analysis interpretation because they did not have a matching LA-ICP-MS analysis of Mg/Ca for comparison (see below in section 2.4). A data table including all raw and corrected sample and standard measurements is included as Appendix A.

2.3. Oxygen isotope analysis by Isotope Ratio Mass Spectrometry.

To compare the high-resolution SIMS data with typical whole-test analysis, we analyzed $\delta^{18}O$ in *Uvigerina* spp. from the same core sections by conventional means (Kiel-device with Isotope Ratio Mass Spectrometer IR-MS). The foraminifera were analyzed at the University of California Santa Cruz, Stable Isotope Laboratory using a Finnigan Isotope Ratio Mass Spectrometer (IR-MS, MAT-256) with a Kiel auto-carbonate device (using an in-house crystalline Carrera Marble standard, CM12, calibrated against international standards and NBS-19 crystalline carbonate standards). The tests used for conventional analysis were picked from the same vial/split as the tests used for SIMS analysis but are not the identical individuals. Between 12 and 15 specimens were picked from each sample, cleaned and gently crushed. Individuals between 355 and 250 μm size fraction were used to eliminate variability based on size. All the data are expressed using standard delta (δ) notation in per mil (‰) relative to Vienna Pee Dee Belemnite standard and the reproducibility (1σ) of the NBS-19 standard was ±0.05‰ for $\delta^{18}O$ during these analyses (Appendix B).

2.4. Analysis by LA-ICP-MS (12 μm spots and 50 μm spots).

We performed LA-ICP-MS analysis on *Uvigerina* spp. specimens with a Teledyne Photon Machines Analyte Excite laser (193 nm) and Thermo X Series II ICP-MS. Laser analysis spots were targeted to be adjacent to the SIMS analysis using the same epoxy mounts (i.e. same tests). Between SIMS and LA-ICP-MS analysis, the mounts were gently polished to remove the gold coating required for SIMS analysis. The advantage of measuring the samples by both techniques is that it allows for a more direct comparison between analytical methods and the various geochemical tracers obtained using these methods. One disadvantage of using epoxy mounts for LA-ICP-MS analysis is that the spot size, and thus analytical sensitivity, is spatially limited by the exposed cross-section of the test wall. Thus, we use a 12 μm spot size, which is smaller than the typical 50-μm spot used for non-epoxy mounted LA-ICP-MS analyses. The 12 μm spots were carefully targeted to be in test areas with no pores, and well inside the edge of the test walls to avoid contamination bias in the measurements. To the best of our ability, laser spots were placed as close as possible to the SIMS analyses pits, however, this was not possible for some tests since the sample exposures were slightly altered during polishing between the two procedures (see Figures 2 and 3). Pre-ablation of the spots (5Hz, 5 shots, 0.4 J/cm^3) was performed to clean the surface area. Approximately two to six laser spots (10Hz, 200 shots, 1.83 J/cm^2), 12 μm in diameter, were ablated on each of the tests. These data are presented in the supplemental material as Appendix C, and were acquired for masses 24-Mg, 44-Ca, and 88-Sr. NIST 610 was analyzed with the same parameters and used for elemental calibration. Long-term reproducibility of the Mg/Ca ratio in NIST 610 (nominal values of 432 ppm, GeoRem, 6/2011), was 8.66 ± 0.14 mmol mol^{-1} (1σ, n = 150 over 5 analytical days). We assume that the analytical reproducibility using the standards is equivalent to that of the foraminifera, which we cannot assess directly since each measurement of the foraminifera destroys that portion of the sample, and repeated measurements are not possible. Repeated measurements on different locations in the same foraminifera are subject to larger variability inherent to the organism (representing short term environmental changes over the life span of each individual and vital effects).

We then obtained 50-μm spot analyses by the more traditional depth-profiling LA-ICP-MS procedure on uncast, whole foraminifera taken from the same sediment samples. Specimens were picked from the same six sediment splits from which tests were picked to make the epoxy mount used for LA-ICP-MS and SIMS analysis (but different individuals). Individuals of similar size were analyzed to ensure the least variability based on size (250-355 μm). Because of low sample availability, it was not possible to depth-profile the same number of tests for each time slice (in total 29 tests were used versus the 38 that were measured in the epoxy mounts). For consistency and to allow direct comparison with the procedure used for the foraminifera mounted in epoxy, the sample cleaning consisted of multiple ultrasonication steps in MilliQ water and methanol and additional rinses with MilliQ water. The tests were adhered to a glass slide using carbon tape (rather than embedded and polished in the epoxy). The sampling spots were pre-ablated (5Hz, 5 shots, 0.4 J/cm^2) before data acquisition to clean the surface area. Approximately two to six laser spots (10Hz, 200 shots, 1.83 J/cm^2), 50 µm in diameter, were ablated on each of the tests. All the data are presented in supplemental material as Appendix D, and were acquired for masses 24-Mg, 44-Ca, 55-Mn, and 88-Sr. NIST 610 was analyzed with the same parameters used for the epoxy mount and used for elemental calibration (reproducibility of the Mg/Ca ratio in NIST 610 analyzed with these samples was 8.74 ± 0.14 mmol mol^{-1} (1σ, n = 150 over 5 analytical days). As noted above the reproducibility of different spots obtained on each test is much lower than that of the standard as it incorporates real natural variability and unknown vital effects.

2.5. Bulk ICP-MS element ratio measurements

Bulk Mg/Ca and Sr/Ca ratios were measured by ICP-MS (Finnigan Elemental XR) at UCSC using the procedure described in Quintana Krupinski et al. (2017). Between 9 and 12 specimens were picked from each of the six time-intervals, from the same samples used for LA-ICP-MS and SIMS analysis. Individuals of similar size were analyzed to ensure the least variability based on size (250-355 µm). The specimens were crushed, and sample cleaning consisted of multiple ultrasonication steps in MilliQ water and methanol, a reductive and oxidative step and additional rinses with MilliQ water following the protocol by Quintana Krupinski et al. (2017). The reductive step was included in the cleaning procedures to remove Mg associated with remnant organic matter and adsorbed phases (Boyle and Keigwin, 1985; Brian and Martin, 2010; Quintana Krupinski et al., 2017). The cleaned tests were transferred to acid-cleaned Eppendorf vials on the day of analysis and dissolved in 400 µL of 0.075 HNO_3 (Optima grade) prior to analysis. The between-run reproducibility (based on measurement of the liquid consistency standard and blank after every 3 samples) was ±0.3% (1σ) for both Mg/Ca and Sr/Ca, and the in-run reproducibility was ±0.4% (1σ). These data are presented in the supplemental material Appendix B.

2.6. Data Treatment

Images of each specimen analyzed by SIMS and LA-ICP-MS were taken using a Scanning Electron Microscope (SEM). These high-resolution images helped ensure that the measurements were taken on the same layer of growth of the shell and to avoid contamination due to the presence of pores and/or channel on the shell analyzed (see examples in Figure 2 and 3). Moreover, all the elemental ratio measurements (12- and 50-µm spots) are time resolved. Thus, every measurement has been manually examined making sure to identify contaminant phases or anomalous spikes. Most of the time-resolved trace element profiles show an enriched zone of high Mg/Ca at the start of each analysis, followed by an interval of relatively constant and lower Mg/Ca, consistent with observations reported in previous *in situ* laser ablation studies of foraminifera (Creech et al., 2010 and reference there-in). The software that was utilized, Thermo PlasmaLab, permits screening the raw data and thus filtering each laser profile to remove suspect contaminate interferences, usually represented by sudden peaks of Mg or Mn (example in Figure 4; Mn was monitored only for the 50 µm spots due to a weak signal from the 12 µm spots). We then compared the screened measurements from the different spot sizes (12-µm in epoxy versus 50-µm in uncast whole foraminifera) and for the bulk analysis. To compare the different spot sizes obtained with the LA-ICP-MS methodologies (12-µm spot in epoxies (N= 38 tests in total) versus 50-µm spot on whole foraminifera (N= 29 tests in total) and bulk analyses (N= between 9 and 12 tests for each sample)) we calculated element/Ca means and standard deviations using the R software package. To compare $\delta^{18}O$ and trace element results, we generated regressions utilizing the average composition of each foraminifer and for each time slice while also indicating the different chambers in which the measurements were taken, (two examples in Figure 2 and 3). The bivariate least-square regressions were generated using PAST software (Hammer et al., 2001).

3. Results

3.1. *In situ* $\delta^{18}O$ measurements

In situ SIMS $\delta^{18}O$ measurements (reported on the VPDB scale) vary between 0.7–2.6‰ in the Holocene and between 1.4‰ and 3.0‰ during the YD (Appendix A). The background-corrected OH/O ratios varied between 0.005-0.01 within the *Uvigerina* tests measured in this study (Appendix A). Simultaneous measurement of OH/O accompanies all carbonate $\delta^{18}O$ analyses at WiscSIMS. Its measurement was originally intended for use during data screening to monitor the relative amount of H-bearing species (i.e., not calcite) included within a sputtered spot. Over time, OH/O observations in many carbonate types (biologically mediated and abiotic) have revealed some intriguing patterns, including intra- and inter-sample anticorrelations between $\delta^{18}O$ and OH/O (Orland et al., 2015; Wycech et al., 2018a and b; Helser et al., 2018). In any sample, OH/O likely indicates the amount of water and/or organic material included in each SIMS spot, but it is unknown if there is causality between elevated OH/O and lower $\delta^{18}O$ values. As such, quantitative interpretation of the OH/O metric remains unclear and is beyond the scope of this study.

3.2. Traditional $\delta^{18}O$ measurements

$\delta^{18}O$ data measured with the bulk technique are systematically higher than those measured by SIMS, ranging from 2.8–2.9‰ in the Holocene, and from 3.1–3.4‰ in the YD (Appendix B). The relative difference between average $\delta^{18}O$ measurements from the Early Holocene and YD is ~1.0‰ for both techniques (Appendix B).

3.3. In situ Elemental Ratios

Values for Mg/Ca of individual specimens for the 12-µm spot analyses ranged from 0.6 to 1.3 mmol mol^{-1} in the Holocene, and between 0.5 and 1.7 mmol mol^{-1} in the YD (Figure 5, Appendix C). For 50 µm spot analyses, Mg/Ca values are between 0.6 and 2 mmol mol^{-1} in the Holocene and between 0.8 and 1.7 mmol mol^{-1} in the YD (Appendix D). The Sr/Ca measurements ranged from 1 to 1.4 mmol mol^{-1} for the analyses on the epoxy mounts (12 µm spots) as well as from the depth-profiled foraminifera with 50 µm spots (Appendix C and Appendix D). To test for diagenetic overprinting, we monitored Mn/Ca during depth-profile analyses on the whole foraminifera (50 µm spot) after the pre-ablation (Appendix D). Mn/Ca values were relatively low (average 0.01 and 0.14 mmol mol^{-1}) and within the generally used level of Mn/Ca confirming the absence of diagenetic coatings (between 0.05 mmol/mol and ~0.15 mmol/mol (Boyle, 1983; Boyle and Keigwin, 1985; Delaney, 1990; Ohkouchi et al., 1994; Glock et al., 2012)).

3.4. Traditional Elemental Ratio

The foraminifera bulk measurements are similar and correlated to the *in situ* laser data (12 µm spot) studied in epoxies for both Mg and Sr (r^2= 0.8 and 0.9 respectively). However, the *in situ* depth-profile laser measurements of Mg and Sr from whole foraminifera (50 µm spot) show less correlation with the bulk measurements (r^2= 0.2 and 0.02 respectively) (Figure 6, Appendix C).

4. Discussion

4.1 Geochemical variability within and between *Uvigerina* tests.

For both time intervals (i.e. last 1000 years and YD), the SIMS $\delta^{18}O$ values span a range of 1.9‰, which is remarkably high if we consider that the species is benthic and hence seasonal environmental changes and habitat depth are not expected to vary much. Specifically, *Uvigerina* generally prefers a shallow infaunal habitat (Corliss and Emerson, 1990; Ernst and van der Zwaan, 2004; Davis et al., 2016) and samples were obtained from sediments at a depth of 901 m of seawater. However, the difference in the average values between the two time-intervals is consistent with lower temperatures or higher salinity (higher $\delta^{18}O$) in the YD bottom waters (Rickaby and Elderfield, 2005). The Mg/Ca data, in contrast, do not show a significant difference in the values or the range between the two time-intervals. Assuming Mg/Ca data represent bottom water temperatures, the $\delta^{18}O$ difference between the two time-periods suggests that the $\delta^{18}O$ of bottom water and/or pore-water decreased between the YD and Late Holocene.

The *in situ* analyses allow us to calculate a correlation coefficient between Mg/Ca and $\delta^{18}O$ within single foraminifera (see Figures 2 and 3 as two examples). In contrast to the finding of Rollion-Bard et al. (2008) for the benthic foraminifera *Amphistegina*, no correlation is observed in any *Uvigerina* test between the *in situ* Mg/Ca and $\delta^{18}O$ measurements (Figure 7). Furthermore, considering the growth mechanism of the genus *Uvigerina* (Grunlund and Hansen, 1976), and that the paired analysis are within the same growth layer, we do not see any apparent correlation between either geochemical proxy and chamber number, implying that there is no consistent age- or size-related impact on Mg/Ca and $\delta^{18}O$ (Figures 2 and 3). Our results suggest species-specific responses, which warrant further research comparing different benthic foraminifera genus.

Our analyses of *Uvigerina* individuals demonstrate considerable within-genus variability. Other than bias due to the utilized methodologies, there are several effects that could contribute to the observed variability, including biological or “vital” effects and changes over time in the porewater chemistry. We have not used the data to derive temperatures because we expect that the bottom water temperatures varied little within each time slice and thus is not relevant for the aims of this research (e.g., to compare among analytical techniques and between time slices).

Theoretically, if both proxies record the temperature of the pore water, we would expect a strong correlation since bottom water $\delta^{18}O$ is assumed to change little in the open ocean within the time scale represented by each time interval used (Wit et al., 2012). One of the causes for the lack of correlation could be the specific location of Site 1015 (i.e. Santa Monica Basin) and the sensitivity of this location to environmental changes which are then recorded in the genus utilized for this study. Specifically, the basin is relatively deep and different water masses with distinct characteristics of temperature, salinity and origin may have filled the basin during the different time slices analyzed here and contributed to the lack of correlation between Mg/Ca and $\delta^{18}O$ when comparing data from the last 1000 years to that of the YD (Figure 7). It has been shown that the benthic foraminifera investigated in this study can calcify in low bottom water oxygenation levels (Moffit et al., 2014, 2015; Ohkushi et al., 2013; Balestra et al., 2018). Thus, it is also possible that Mg/Ca ratios in *Uvigerina* particularly at this location, are sensitive to different growth and calcification conditions, such as food availability or carbonate chemistry (Wit et al., 2010), which could contribute to the lack of correlation seen in the data.

4.2 Comparison of bulk and *in situ* analytical techniques.

4.2.1 $\delta^{18}O$

An offset of ~1‰ is observed between the $\delta^{18}O$ values of *Uvigerina* measured by SIMS and those measured by traditional bulk gas isotope ratio mass spectrometry (IRMS) (Figure 5). This offset, (SIMS $\delta^{18}O$ values ~1‰ lower than measured by IRMS) and the average background-corrected OH/O ratio of 0.008 (Appendix A) are consistent with IRMS-SIMS comparison studies reported in other low-temperature carbonates, including foraminifera (Orland et al., 2015; Wycech et al., 2018a). Here, the existence of a 1‰ offset is notable because it matches the offset observed by Rollion-Bard et al. (2008) between the secondary calcite in their cultured benthic foraminifera and the expected $\delta^{18}O$ value. The IRMS-SIMS $\delta^{18}O$ offset is likely the result of matrix effects on the SIMS data (i.e., the inclusion of water and/or organic materials within the sputtered sample volume (Orland et al., 2015; Wycech et al., 2018b), and possibly the related effect of trace element content on the SIMS measurements (Sliwinski et al., 2017). While experiments are underway to clarify the origin of the offset, we note that the $\delta^{18}O$ offset is uniform across the population of *Uvigerina* tests analyzed in this study. The precision of the SIMS analyses is established by a rigorous approach to standardization, so the relative inter- and intra-shell $\delta^{18}O$ variability we observe (regardless of the offset in absolute values) and the previously mentioned lack of correlation to Mg/Ca suggests that factors beyond temperature contribute to the $\delta^{18}O$ of *Uvigerina* test calcite in the Santa Monica basin.

4.2.2 Mg/Ca and Sr/Ca

We found considerable variability in the Mg/Ca data within and among individual specimens of the same genus and time slice. Variability among different individual foraminifera has been clearly shown in cultured foraminifera (Dissard et al., 2010; Duenas-Bohorquez et al., 2011) including benthic species (Wit et al., 2012). Thus, in addition to analytical errors, the variability in the Mg/Ca data is due to short time-scale (diurnal, seasonal, decadal) environmental variability and biological effects related to differences among individuals even if they belong to the same genus and were collected in samples representing the same time-interval (Wit et al., 2012).

A strong correlation is observed between the 12 μm spots and bulk analyses in both Mg/Ca and Sr/Ca analyses. The agreement between the 12 μm and the bulk analyses and their lack of agreement with the larger 50 μm depth-profiling of whole foraminifera may be explained by real differences in the material included in each analysis. Specifically, the bulk analysis was done on crushed and chemically cleaned specimens using a procedure that removes a considerable amount of surface-bound organic matter and may preferentially remove high-Mg calcite (Brian and Martin, 2010). In contrast, the foraminifera samples that were analyzed by laser (both 50 μm and 12 μm spot methods) were only cleaned by sonication and rinsing with methanol and water (a procedure that does not necessary remove all the organic matter present on the shell). There is a critical difference between the laser methods, however, in that 50 μm depth-profiling indiscriminately includes all material between the sample surface and bottom of the laser pit whereas the 12 μm analysis of the cross section uses SEM imaging to avoid contamination that may be present on the surface or in cracks of the sample.

We suggest that the use of the 12 μm beam to analyze a shell in cross-section together with SEM imaging allows measurement of Mg/Ca in better-preserved or less-contaminated domains than the 50 μm depth-profiling technique. The correlation observed between bulk and 12μm Mg/Ca results indicates that although the reductive cleaning may have lowered the Mg/Ca of bulk material, the relative Mg/Ca is preserved. In planktonic tests it has been suggested that Mg/Ca ratios obtained by LA-ICP-MS on whole foraminifera (50 µm spots) could record a large range of values that are not related to environmental temperatures but instead to the presence of detrital material on the test (Eggins et al., 2003 and references therein). However, it is also possible that the application of different cleaning techniques plays a significant role in determining the result of the analysis (Sadekov et al., 2008). Another possibility could be that the lack of significant correlation between the 50 µm and 12 µm *in situ* analyses is due to the limited number of foraminifera analyzed. We suggest that further work is warranted to compare depth-profiling analyses of element/Ca to small spot, cross-section analyses where care is taken to avoid organic-rich or porous domains. Such a study would be particularly useful if both types of analyses could be completed in a single individual (e.g. Wycech et al., 2018a).

5. Conclusion

In this study, we apply bulk and high-resolution *in situ* analytical methodologies to obtain $\delta^{18}O$, Mg/Ca and Sr/Ca values from the benthic foraminifera genus *Uvigerina*. We show an approach for obtaining paired, *in situ* measurements of element/Ca ratios by LA-ICPMS and $\delta^{18}O$ by SIMS within the same individual benthic foraminifera. For both the element/Ca and $\delta^{18}O$ proxies, the same range of values is seen in the averaged *in situ* measurements as in the bulk foraminifera, but there are varying degrees of correlation between the different analytical methodologies. The large intra-shell variability for each of the proxies measured by *in situ* methodologies (12 µm and 50 µm spots) does not follow chamber number, which implies that there are no significant size(age)-related impacts on Mg/Ca, Sr/Ca and $\delta^{18}O$ for this species. Further, the intra-shell variability is not correlated between the above geochemical proxies. We surmise that the differences between proxies for the time slices we examined and the correlations (or lack thereof) between the proxies that we reported, are due to a combination of 1) real variability in the water chemistry from which the individual foraminifera tests were precipitated, and 2) biological responses of the foraminifera to different growth conditions. The biological mechanisms behind this natural variability are still unknown (Wit et al., 2012), and most importantly they could be unique to specific setting and environmental characteristics (e.g., Santa Monica Basin in this case). Our data also demonstrate large inter-shell variability in all three geochemical proxies (Mg/Ca, Sr/Ca and $\delta^{18}O$) analyzed in *Uvigerina* where environmental conditions are expected to be less variable than in the surface ocean. This observed variability may represent some combination of: 1) real environmental conditions specific to the study site (samples from the deep ocean could verify if this is unique to coastal settings), 2) vital effects on individual specimens as seen in culture studies, or 3) variability in non-calcite phases included in the analysis (e.g. intra-crystalline organic matter or other contaminating phases) that strongly depend on cleaning and ablation conditions. This study illustrates the complexities of micro-scale geochemistry inherent to benthic *Uvigerina* foraminifera and demonstrates that inter- and intra-shell variability should be expected when constructing paleoclimate proxy records.

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Appendix A: Summary table for the SIMS data on the foraminifera analyzed.

File	sample	comment	$\delta^{18}O$ ‰ VSMOW	2SD (ext.)	$\delta^{18}O$ ‰ VPDB	Mass Bias (‰)	$\delta^{18}O$ ‰ measured	2SE (int.)	^{16}O (Gcps)	IP (nA)	Yield (Gcps/nA)	Relative Yield	X	Y	$^{16}OH/^{16}O$	OH/O-corrected
	UWC-3		12.49													
	8/24/2015															
20150824@1.asc	WI-STD-83 UWC-3 G1						5.154	0.556	2.117	0.902	2.346		740	422	5.52E-04	
20150824@2.asc	WI-STD-83 UWC-3 G1						5.019	0.603	2.296	0.966	2.378		765	432	5.23E-04	
20150824@3.asc	WI-STD-83 UWC-3 G1						5.117	0.551	2.543	1.100	2.312		756	448	5.17E-04	
20150824@4.asc	WI-STD-83 UWC-3 G1						4.829	0.500	2.552	1.115	2.290		716	465	4.46E-04	
20150824@5.asc	WI-STD-83 UWC-3 G1						4.990	0.519	2.653	1.141	2.325		730	440	5.12E-04	
20150824@6.asc	WI-STD-83 UWC-3 G1						4.920	0.408	2.664	1.172	2.273		754	467	5.40E-04	
	average and 2SD					-7.43	4.964	0.243								
	8/25/2015															
	SBB2015-2															
20150824@7.asc	SBB2015-2 UWC3 G1						5.140	0.410	2.673	1.192	2.243		-565	-124	1.38E-03	
20150824@8.asc	SBB2015-2 UWC3 G1						4.703	0.442	2.687	1.186	2.265		-581	-136	1.49E-03	
20150824@9.asc	SBB2015-2 UWC3 G1						4.955	0.592	2.668	1.182	2.258		-600	-141	1.51E-03	
20150824@10.asc	SBB2015-2 UWC3 G1						5.020	0.507	2.668	1.176	2.269		-591	-158	1.60E-03	
20150824@11.asc	SBB2015-2 UWC3 G1						4.985	0.506	2.630	1.169	2.251		-627	-149	1.56E-03	
	average and 2SD						4.916	0.289								
			VSMOW	2SD	VPDB											
20150824@12.asc	SBB2015-2	unrelated analysis	24.02	0.36	-6.69		16.391	0.824	1.104	1.157	0.954	0.420	-760	3033	2.37E-02	0.022
20150824@13.asc	SBB2015-2	unrelated analysis	27.77	0.36	-3.04		20.121	1.049	1.806	1.148	1.573	0.692	-776	3045	1.90E-02	0.017
20150824@14.asc	SBB2015-2	unrelated analysis	26.79	0.36	-4.00		19.144	0.711	1.994	1.139	1.751	0.770	-811	3004	2.07E-02	0.019
20150824@15.asc	SBB2015-2	unrelated analysis	29.36	0.36	-1.50		21.697	0.880	1.994	1.129	1.767	0.777	-891	3016	1.94E-02	0.018
20150824@16.asc	SBB2015-2	unrelated analysis	32.96	0.36	1.99		25.268	0.439	2.433	1.119	2.174	0.957	-833	3199	8.66E-03	0.007
20150824@17.asc	SBB2015-2	unrelated analysis	31.30	0.36	0.38		23.619	0.611	2.228	1.110	2.006	0.883	-827	3212	1.43E-02	0.013
20150824@18.asc	SBB2015-2	unrelated analysis	24.69	0.36	-6.03		17.065	0.920	0.784	1.107	0.708	0.311	-756	3049	2.65E-02	0.025
20150824@19.asc	SBB2015-2	unrelated analysis	32.33	0.36	1.38		24.646	0.464	2.317	1.095	2.117	0.931	-842	3210	1.16E-02	0.010
20150824@20.asc	SBB2015-UWC3 G1						4.907	0.500	2.488	1.088	2.287		-606	-83	1.63E-03	
20150824@21.asc	SBB2015-UWC3 G1						5.000	0.593	2.474	1.081	2.288		-590	-92	1.76E-03	
20150824@22.asc	SBB2015-UWC3 G1						5.296	0.517	2.564	1.119	2.291		-613	-99	1.89E-03	
20150824@23.asc	SBB2015-UWC3 G1						4.748	0.470	2.657	1.168	2.275		-629	-106	1.81E-03	
	bracket average and 2SD					-7.45	4.952	0.364			2.273				0.002	
			VSMOW	2SD	VPDB											
20150824@24.asc	SBB2015-2	unrelated analysis	30.75	0.40	-0.16		23.055	0.625	2.358	1.199	1.966	0.864	-889	3123	1.30E-02	0.011
20150824@25.asc	SBB2015-2	unrelated analysis	32.06	0.40	1.12		24.359	0.529	2.505	1.196	2.095	0.921	-935	3177	1.32E-02	0.011
20150824@26.asc	SBB2015-2	unrelated analysis	31.62	0.40	0.69		23.915	0.473	2.455	1.179	2.083	0.916	-947	3183	1.44E-02	0.013
20150824@27.asc	SBB2015-2	unrelated analysis	30.69	0.40	-0.21		22.998	0.565	2.373	1.169	2.030	0.893	290	3214	1.49E-02	0.013
20150824@28.asc	SBB2015-2	unrelated analysis	32.88	0.40	1.91		25.172	0.532	2.530	1.162	2.177	0.957	352	3294	8.01E-03	0.006
20150824@29.asc	SBB2015-2	unrelated analysis	33.31	0.40	2.33		25.595	0.578	2.509	1.156	2.171	0.954	340	3290	8.07E-03	0.006
20150824@30.asc	SBB2015-2	unrelated analysis	32.80	0.40	1.83		25.085	0.548	2.505	1.147	2.184	0.960	324	3283	8.43E-03	0.007
20150824@31.asc	SBB2015-2	unrelated analysis	32.30	0.40	1.35		24.598	0.611	2.450	1.139	2.151	0.946	309	3267	1.06E-02	0.009
20150824@32.asc	SBB2015-2	unrelated analysis	32.74	0.40	1.78		25.032	0.440	2.450	1.131	2.166	0.952	282	3195	9.08E-03	0.007
20150824@33.asc	SBB2015-2	unrelated analysis	32.77	0.40	1.81		25.061	0.559	2.427	1.125	2.158	0.949	274	3183	9.16E-03	0.007
20150824@34.asc	SBB2015-UWC3 - G1						4.812	0.597	2.524	1.116	2.262		-729	-156	1.85E-03	
20150824@35.asc	SBB2015-UWC3 - G1						4.989	0.543	2.499	1.110	2.252		-716	-146	1.72E-03	
20150824@36.asc	SBB2015-UWC3 - G1						4.648	0.433	2.581	1.139	2.267		-751	-146	1.86E-03	
20150824@37.asc	SBB2015-UWC3 - G1						5.051	0.423	2.644	1.163	2.273		-730	-139	1.90E-03	
	bracket average and 2SD					-7.47	4.931	0.403			2.274				0.002	
			VSMOW	2SD	VPDB											
20150824@38.asc	SBB20152	unrelated analysis	32.90	0.36	1.93		25.107	0.561	2.444	1.163	2.102	0.929	462	3063	8.84E-03	0.007
20150824@39.asc	SBB20152	unrelated analysis	33.12	0.36	2.14		25.322	0.461	2.499	1.158	2.158	0.954	473	3119	8.05E-03	0.006
20150824@40.asc	SBB20152	unrelated analysis	29.54	0.36	-1.33		21.777	0.570	2.160	1.154	1.873	0.828	385	3195	1.56E-02	0.014
20150824@41.asc	SBB20152	unrelated analysis	32.72	0.36	1.76		24.933	0.530	2.470	1.149	2.149	0.951	356	3153	1.04E-02	0.009
20150824@42.asc	SBB20152	unrelated analysis	32.17	0.36	1.22		24.384	0.528	2.401	1.142	2.103	0.930	356	3141	1.12E-02	0.009
20150824@43.asc	SBB20152	unrelated analysis	32.22	0.36	1.27		24.431	0.561	2.319	1.138	2.037	0.901	91	3462	1.15E-02	0.010
20150824@44.asc	SBB20152	unrelated analysis	32.24	0.36	1.29		24.455	0.756	2.322	1.134	2.048	0.905	188	3418	1.23E-02	0.011
20150824@45.asc	SBB20152	unrelated analysis	32.75	0.36	1.79		24.962	0.462	2.430	1.125	2.159	0.955	1252	3306	1.32E-02	0.011
20150824@46.asc	SBB2015-UWC3-G1						4.929	0.514	2.550	1.125	2.268		-731	-88	1.74E-03	
20150824@47.asc	SBB2015-UWC3-G1						4.990	0.379	2.525	1.119	2.257		-724	-68	1.77E-03	
20150824@48.asc	SBB2015-UWC3-G1						4.852	0.476	2.637	1.173	2.247		-721	-52	1.76E-03	
20150824@49.asc	SBB2015-UWC3-G1						4.543	0.418	2.660	1.175	2.265		-746	-76	1.92E-03	
	bracket average and 2SD					-7.54	4.852	0.356			2.261				0.002	
			VSMOW	2SD	VPDB											
20150824@50.asc	SBB2015-2	unrelated analysis	32.68	0.48	1.72		25.034	0.522	2.564	1.167	2.196	0.971	1252	3271	8.75E-03	0.007
20150824@51.asc	SBB2015-2	unrelated analysis	32.17	0.48	1.22		24.530	0.482	2.509	1.165	2.154	0.952	1230	3103	1.03E-02	0.008
20150824@52.asc	SBB2015-2	unrelated analysis	33.05	0.48	2.08		25.405	0.442	2.542	1.157	2.197	0.971	1286	3167	8.15E-03	0.006
20150824@53.asc	SBB2015-2	unrelated analysis	32.70	0.48	1.74		25.057	0.567	2.450	1.151	2.128	0.941	1282	3182	1.14E-02	0.009
20150824@54.asc	SBB2015-2	unrelated analysis	32.18	0.48	1.23		24.542	0.526	2.450	1.144	2.142	0.947	1402	3159	9.81E-03	0.008
20150824@55.asc	SBB2015-2	unrelated analysis	33.02	0.48	2.05		25.375	0.490	2.524	1.139	2.216	0.980	1349	3304	7.90E-03	0.006
20150824@56.asc	SBB2015-2	unrelated analysis	32.58	0.48	1.62		24.939	0.522	2.466	1.133	2.176	0.962	1385	3386	1.03E-02	0.008
20150824@57.asc	SBB2015-2	unrelated analysis	32.94	0.48	1.97		25.291	0.531	2.379	1.127	2.110	0.933	1376	3461	9.05E-03	0.007
20150824@58.asc	SBB2015-UWC3-G1						5.076	0.552	2.540	1.118	2.273		-671	-124	1.83E-03	
20150824@59.asc	SBB2015-UWC3-G1						5.363	0.489	2.500	1.119	2.235		-647	-104	3.50E-03	
20150824@60.asc	SBB2015-UWC3-G1						5.066	0.505	2.628	1.148	2.289		-623	-120	1.75E-03	
20150824@61.asc	SBB2015-UWC3-G1						5.144	0.497	2.642	1.167	2.264		-694	-122	1.62E-03	
	bracket average and 2SD					-7.40	4.995	0.477			2.262				0.002	
			VSMOW	2SD	VPDB											
20150824@62.asc	SBB2015-2.2.1-1		32.96	0.23	1.99		25.445	0.563	2.497	1.161	2.152	0.952	-2595	1807	9.31E-03	0.007
20150824@63.asc	SBB2015-2.2.1-2		32.91	0.23	1.94		25.389	0.469	2.487	1.158	2.148	0.950	-2553	1970	9.34E-03	0.007
20150824@64.asc	SBB2015-2.2.1-3		32.38	0.23	1.42		24.864	0.473	2.450	1.155	2.121	0.938	-2546	1757	1.26E-02	0.011
20150824@65.asc	SBB2015-2.2.1-4		32.82	0.23	1.86		25.305	0.447	2.499	1.149	2.175	0.962	-2552	1667	8.53E-03	0.007
20150824@66.asc	SBB2015-2.2.2-1		33.25	0.23	2.27		25.731	0.511	2.516	1.140	2.207	0.977	-1270	1611	7.11E-03	0.005
20150824@67.asc	SBB2015-2.2.2-2	not used (low yield)	30.52	0.23	-0.38		23.021	0.635	2.210	1.139	1.940	0.858	-1362	1853	1.66E-02	0.015
20150824@68.asc	SBB2015-2.2.2-3		33.20	0.23	2.22		25.680	0.419	2.443	1.132	2.159	0.955	-1280	1709	7.22E-03	0.005
20150824@69.asc	SBB2015-2.2.2-4		32.91	0.23	1.94		25.387	0.543	2.471	1.127	2.191	0.970	-1344	1690	7.56E-03	0.006
20150824@70.asc	SBB2015-UWC3- G1						5.177	0.514	2.516	1.121	2.245		-648	-35	1.54E-03	
20150824@71.asc	SBB2015-UWC3-G1						4.978	0.495	2.530	1.116	2.268		-674	-26	1.57E-03	
20150824@72.asc	SBB2015-UWC3-G1						5.054	0.504	2.609	1.152	2.265		-651	-8	1.56E-03	
20150824@73.asc	SBB2015-UWC3- G1						5.101	0.460	2.633	1.173	2.245		-628	3	1.52E-03	
	bracket average and 2SD					-7.28	5.120	0.230			2.260				0.002	
			VSMOW	2SD	VPDB											
20150824@74.asc	SBB2015-2.2.3-1	not used (no LA)	32.71	0.27	1.74		25.139	0.463	2.506	1.178	2.128	0.942	-318	2214	1.25E-02	0.011
20150824@75.asc	SBB2015-2.2.3-2		32.69	0.27	1.72		25.118	0.560	2.489	1.176	2.117	0.936	-287	1982	1.20E-02	0.010
20150824@76.asc	SBB2015-2.2.3-3		33.25	0.27	2.27		25.680	0.466	2.568	1.174	2.188	0.968	-309	1773	9.85E-03	0.008
20150824@77.asc	SBB2015-2.2.4-1		33.13	0.27	2.15		25.559	0.457	2.507	1.168	2.147	0.950	955	1841	1.13E-02	0.010
20150824@78.asc	SBB2015-2.2.4-2		32.81	0.27	1.85		25.246	0.489	2.530	1.165	2.172	0.961	834	1733	9.41E-03	0.008
20150824@79.asc	SBB2015-2.2.4-3	not used (no LA)	32.83	0.27	1.86		25.259	0.474	2.542	1.162	2.188	0.968	849	1739	8.94E-03	0.007
20150824@80.asc	SBB2015-2.2.4-4		32.93	0.27	1.96		25.360	0.530	2.510	1.157	2.169	0.960	858	1747	9.27E-03	0.008
20150824@81.asc	SBB2015-2.2.5-1		32.37	0.27	1.41		24.802	0.565	2.485	1.152	2.157	0.954	1951	1907	8.70E-03	0.007
20150824@82.asc	SBB2015-2.2.5-2		32.53	0.27	1.57		24.967	0.449	2.442	1.146	2.131	0.943	1978	1946	1.14E-02	0.010
20150824@83.asc	SBB2015-2.2.5-3		32.93	0.27	1.96		25.363	0.502	2.430	1.140	2.131	0.943	1992	1735	8.94E-03	0.007
20150824@84.asc	SBB2015-2.2.6-1	not used (no LA)	31.10	0.27	0.18		23.540	1.780	1.672	1.142	1.464	0.648	3124	1693	1.61E-02	0.015
20150824@85.asc	SBB2015-2.2.6-2	not used (no LA)	32.03	0.27	1.09		24.468	0.426	2.415	1.125	2.146	0.950	3022	1610	1.13E-02	0.010
20150824@86.asc	SBB2015-UWC3-G1						5.227	0.454	2.516	1.115	2.256		-580	-53	1.60E-03	
20150824@87.asc	SBB2015-UWC3-G1						5.212	0.502	2.506	1.110	2.256		-568	-37	1.61E-03	
20150824@88.asc	SBB2015-UWC3-G1						4.986	0.487	2.587	1.139	2.272		-548	-36	1.54E-03	
20150824@89.asc	SBB2015-UWC3-G1						4.828	0.513	2.642	1.162	2.274		-577	-19	1.66E-03	
	bracket average and 2SD					-7.33	5.070	0.274			2.260				0.002	
			VSMOW	2SD	VPDB											
20150824@90.asc	SBB2015-2.2.6-3	not used (no LA)	32.63	0.40	1.66		25.083	0.496	2.175	1.174	1.852	0.816	3036	1840	1.19E-02	0.010
20150824@91.asc	SBB2015-2.2.7-1	not used (no LA)	33.04	0.40	2.07		25.498	0.600	2.419	1.152	2.099	0.926	3729	1911	1.35E-02	0.012
20150824@92.asc	SBB2015-2.2.7-2	not used (no LA)	33.00	0.40	2.03		25.454	0.526	2.423	1.144	2.119	0.934	3784	1580	1.08E-02	0.009
20150824@93.asc	SBB2015-2.2.7-3	not used (no LA)	33.40	0.40	2.42		25.851	0.523	2.479	1.137	2.181	0.961	4007	1550	7.91E-03	0.006
20150824@94.asc	SBB2015-2.3.1-1		32.17	0.40	1.23		24.634	0.514	2.335	1.118	2.088	0.921	-4771	673	1.10E-02	0.009
20150824@95.asc	SBB2015-UWC3-G1						5.233	0.396	2.542	1.115	2.279		-541	-116	1.61E-03	
20150824@96.asc	SBB2015-UWC3-G1						5.222	0.509	2.518	1.114	2.261		-521	-106	1.61E-03	
20150824@97.asc	SBB2015-UWC3-G1						5.265	0.552	2.520	1.109	2.273		-517	-132	1.84E-03	
20150824@98.asc	SBB2015-UWC3-G1						4.777	0.436	2.592	1.140	2.273		-516	-86	1.64E-03	
	bracket average and 2SD					-7.31	5.094	0.400			2.268				0.002	
			VSMOW	2SD	VPDB											
20150824@99.asc	SBB2015-2.3.1-2;		32.90	0.33	1.93		25.392	0.498	2.480	1.169	2.121	0.933	-4727	525	8.14E-03	0.006
20150824@100.asc	SBB2015-2.3.1-3;	not used (no LA)	32.69	0.33	1.73		25.191	0.486	2.379	1.173	2.028	0.892	-4657	465	8.75E-03	0.006
20150824@101.asc	SBB2015-2.3.2-1;		32.81	0.33	1.84		25.307	0.536	2.488	1.163	2.139	0.941	-3965	468	1.01E-02	0.008
20150824@102.asc	SBB2015-2.3.2-2;		33.11	0.33	2.13		25.599	0.512	2.519	1.162	2.168	0.954	-3900	586	7.97E-03	0.006
20150824@103.asc	SBB2015-2.3.2-3;		31.59	0.33	0.66		24.099	0.535	2.397	1.158	2.069	0.910	-3905	810	1.25E-02	0.010

20150824@104.asc	SBB2015-2.3.2-4;		33.41	0.33	2.42		25.901	0.441	2.461	1.153	2.134	0.939	-3943	748	7.89E-03	0.006
20150824@105.asc	SBB2015-2.3.2-5;	not used (no LA)	30.24	0.33	-0.65		22.753	0.847	1.996	1.150	1.736	0.764	-3791	813	1.50E-02	0.013
20150824@106.asc	SBB2015-2.3.2-6;		32.50	0.33	1.54		24.997	0.622	2.433	1.146	2.122	0.934	-3872	860	9.42E-03	0.007
20150824@107.asc	SBB2015-2.3.2-7;		32.37	0.33	1.42		24.872	0.538	2.454	1.143	2.147	0.945	-3818	713	9.46E-03	0.007
20150824@108.asc	SBB2015-2.3.3-1;		30.99	0.33	0.08		23.501	0.646	2.362	1.139	2.074	0.912	-2934	711	1.31E-02	0.011
20150824@109.asc	SBB2015-2.3.3-2;	not used (no LA)	31.00	0.33	0.08		23.504	0.518	2.249	1.133	1.985	0.873	-2877	656	1.36E-02	0.011
20150824@110.asc	SBB2015-2.3.3-3;		32.05	0.33	1.10		24.550	0.472	2.315	1.126	2.057	0.905	-3133	714	1.43E-02	0.012
20150824@111.asc	SBB2015-2.3.3-4;	not used (no LA)	30.72	0.33	-0.18		23.233	0.622	2.139	1.122	1.907	0.839	-3113	707	1.58E-02	0.014
20150824@112.asc	SBB2015-UWC3-G1						5.047	0.587	2.528	1.117	2.263		-540	-148	6.25E-03	
20150824@113.asc	SBB2015-UWC3-G1						5.244	0.469	2.541	1.112	2.285		-545	-75	1.79E-03	
20150824@114.asc	SBB2015-UWC3-G1						5.085	0.502	2.601	1.140	2.281		-525	-47	1.72E-03	
20150824@115.asc	SBB2015-UWC3-G1						5.193	0.506	2.641	1.164	2.268		-507	-31	1.66E-03	
	bracket average and 2SD					-7.27	5.133	0.328			2.273				0.002	
			VSMOW	2SD	VPDB											
20150824@116.asc	SBB2015-2.3.3-5		31.88	0.28	0.94		24.290	0.475	2.426	1.173	2.068	0.910	-2858	368	1.57E-02	0.013
20150824@117.asc	SBB2015-2.3.3-6	not used (no LA)	31.88	0.28	0.94		24.293	0.824	2.228	1.162	1.917	0.844	-3013	361	1.44E-02	0.012
20150824@118.asc	SBB2015-2.3.4-1		32.70	0.28	1.74		25.112	0.495	2.429	1.157	2.100	0.924	-2089	749	9.73E-03	0.007
20150824@119.asc	SBB2015-2.3.4-2	not used (no LA)	31.33	0.28	0.41		23.753	0.607	2.294	1.146	2.001	0.881	-2009	717	1.23E-02	0.010
20150824@120.asc	SBB2015-2.3.4-3		32.55	0.28	1.59		24.960	0.517	2.407	1.141	2.110	0.929	-1932	521	9.78E-03	0.007
20150824@121.asc	SBB2015-2.3.5-1	not used (no LA)	32.71	0.28	1.75		25.122	0.681	2.303	1.135	2.029	0.893	-1193	490	9.84E-03	0.007
20150824@122.asc	SBB2015-2.3.5-2	not used (no LA)	32.63	0.28	1.67		25.044	0.490	2.468	1.133	2.178	0.958	-1365	489	8.80E-03	0.006
20150824@123.asc	SBB2015-2.3.5-3	not used (no LA)	33.74	0.28	2.74		26.137	0.498	2.292	1.135	2.019	0.889	-1408	865	8.01E-03	0.006
20150824@124.asc	SBB2015-2.3.6-1		33.37	0.28	2.38		25.769	0.530	2.457	1.123	2.188	0.963	-1	693	9.16E-03	0.007
20150824@125.asc	SBB2015-UWC3-G1;						4.811	0.443	2.542	1.120	2.270		-609	-178	1.77E-03	
20150824@126.asc	SBB2015-UWC3-G1;						4.971	0.528	2.539	1.118	2.271		-573	-204	1.64E-03	
20150824@127.asc	SBB2015-UWC3-G1;						4.926	0.503	2.612	1.150	2.271		-506	-159	2.86E-03	
20150824@128.asc	SBB2015-UWC3-G1;						5.102	0.530	2.673	1.178	2.268		-529	-168	1.78E-03	
	bracket average and 2SD					-7.35	5.047	0.284			2.272				0.002	
			VSMOW	2SD	VPDB											
20150824@129.asc	SBB2015-2.3.6-2		32.16	0.30	1.21		24.497	0.543	2.496	1.184	2.109	0.928	168	611	1.25E-02	0.011
20150824@130.asc	SBB2015-2.3.6-3		32.85	0.30	1.89		25.189	0.501	2.558	1.182	2.163	0.952	323	686	9.60E-03	0.008
20150824@131.asc	SBB2015-2.3.7-1	not used (no LA)	30.12	0.30	-0.77		22.471	0.536	2.231	1.175	1.900	0.836	1380	635	1.68E-02	0.015
20150824@132.asc	SBB2015-2.3.7-2	not used (no LA)	31.37	0.30	0.45		23.719	0.469	2.354	1.171	2.011	0.885	1382	654	1.22E-02	0.010
20150824@133.asc	SBB2015-2.3.7-3	not used (no LA)	31.16	0.30	0.24		23.503	0.500	2.391	1.165	2.053	0.903	1554	337	1.50E-02	0.013
20150824@134.asc	SBB2015-2.3.8-1	not used (no LA)	33.40	0.30	2.41		25.729	0.465	2.450	1.157	2.117	0.932	2566	655	8.68E-03	0.007
20150824@135.asc	SBB2015-2.3.8-2	not used (no LA)	29.49	0.30	-1.37		21.853	0.807	1.745	1.152	1.515	0.667	2465	688	1.87E-02	0.017
20150824@136.asc	SBB2015-2.3.8-3	not used (no LA)	33.04	0.30	2.06		25.371	0.464	2.439	1.145	2.130	0.938	2529	504	9.89E-03	0.008
20150824@137.asc	SBB2015-UWC3-G1						5.083	0.459	2.586	1.141	2.267		-563	-169	1.84E-03	
20150824@138.asc	SBB2015-UWC3-G1						4.871	0.501	2.592	1.138	2.278		-522	-192	1.88E-03	
20150824@139.asc	SBB2015-UWC3-G1						5.232	0.473	2.662	1.166	2.283		-653	-181	1.68E-03	
20150824@140.asc	SBB2015-UWC3-G1						4.814	0.461	2.707	1.192	2.270		-648	-199	1.73E-03	
	bracket average and 2SD					-7.42	4.976	0.302			2.272				0.002	
	8/26/2015															
	SBB2015-2															
~~20150824@300.asc~~	~~SBB2015-UWC3-G1~~	E-beam off					~~-5.076~~	~~5.246~~	~~0.081~~	~~1.271~~	~~0.064~~		~~-697~~	~~-166~~	~~9.67E-03~~	
20150824@301.asc	SBB2015-UWC3-G1						5.213	0.505	2.516	1.137	2.213		-749	-164	1.46E-03	
20150824@302.asc	SBB2015-UWC3-G1						5.140	0.503	2.543	1.138	2.236		-718	-173	1.49E-03	
20150824@303.asc	SBB2015-UWC3-G1						4.948	0.450	2.631	1.171	2.246		-694	-187	1.47E-03	
20150824@304.asc	SBB2015-UWC3-G1						4.962	0.436	2.679	1.199	2.235		-669	-194	1.51E-03	
	average and 2SD						5.066	0.263								
			VSMOW	2SD	VPDB											
20150824@305.asc	SBB2015-2.3.9-1	not used (no LA)	31.97	0.24	1.02		24.395	0.674	2.395	1.226	1.954	0.876	3626	313	1.17E-02	0.010
20150824@306.asc	SBB2015-2.3.9-2	not used (no LA)	32.77	0.24	1.81		25.196	0.577	2.435	1.224	1.989	0.892	3495	406	1.07E-02	0.009
20150824@307.asc	SBB2015-2.3.9-3	not used (no LA)	32.90	0.24	1.93		25.321	0.463	2.491	1.215	2.051	0.920	3487	654	1.03E-02	0.009
20150824@308.asc	SBB2015-2.3.10-1	not used (no LA)	31.15	0.24	0.23		23.582	0.513	2.337	1.206	1.937	0.869	4497	78	1.33E-02	0.012
20150824@309.asc	SBB2015-2.3.10-2		33.47	0.24	2.49		25.892	0.479	2.496	1.192	2.095	0.939	4493	471	8.21E-03	0.007
20150824@310.asc	SBB2015-2.3.10-3		33.42	0.24	2.44		25.839	0.475	2.502	1.185	2.111	0.947	4471	605	8.52E-03	0.007
20150824@311.asc	SBB2015-2.3.10-4	not used (construction vibration)	32.77	0.24	1.80		25.191	0.598	2.362	1.182	1.998	0.896	4506	161	1.05E-02	0.009
20150824@312.asc	SBB2015-2.5.3-1	not used (construction vibration)	32.42	0.24	1.46		24.844	0.396	2.301	1.172	1.963	0.880	-3931	-2759	8.26E-03	0.007
20150824@313.asc	SBB2015-2.5.3-2		31.67	0.24	0.73		24.096	0.820	2.444	1.168	2.092	0.938	-4033	-2635	1.46E-02	0.013
20150824@314.asc	SBB2015-2.5.3-3		32.99	0.24	2.02		25.415	0.526	2.438	1.161	2.100	0.942	-3947	-3066	1.07E-02	0.009
20150824@315.asc	SBB2015-2.5.4-1		33.21	0.24	2.23		25.627	0.458	2.463	1.158	2.127	0.954	-3036	-2881	9.32E-03	0.008
20150824@316.asc	SBB2015-2.5.4-2		32.84	0.24	1.87		25.260	0.516	2.558	1.149	2.227	0.999	-2967	-2936	1.19E-02	0.010
20150824@317.asc	SBB2015-UWC3-G1;						4.901	0.508	2.551	1.140	2.238		-729	-186	1.69E-03	
20150824@318.asc	SBB2015-UWC3-G1;						5.075	0.514	2.538	1.138	2.231		-715	-219	1.58E-03	
20150824@319.asc	SBB2015-UWC3-G1;						4.967	0.444	2.557	1.135	2.253		-642	-266	1.58E-03	
20150824@320.asc	SBB2015-UWC3-G1;						5.165	0.552	2.492	1.132	2.201		-441	-144	1.53E-03	
20150824@321.asc	SBB2015-UWC3-G1;						5.180	0.521	2.575	1.161	2.219		-409	-141	1.56E-03	
	bracket average and 2SD					-7.34	5.061	0.236			2.230				0.002	
			VSMOW	2SD	VPDB											
20150824@322.asc	SBB2015-2.5.4-3		32.07	0.30	1.12		24.552	0.575	2.459	1.192	2.062	0.928	-3073	-2817	1.14E-02	0.010
20150824@323.asc	SBB2015-2.5.5-1	not used (construction vibration)	32.60	0.30	1.64		25.082	0.595	2.436	1.196	2.037	0.917	-1694	-2626	1.09E-02	0.009
20150824@324.asc	SBB2015-2.5.5-2	not used (construction vibration)	31.86	0.30	0.92		24.350	0.870	2.333	1.196	1.950	0.877	-1469	-2555	2.33E-02	0.022
20150824@325.asc	SBB2015-2.5.5-3	not used (no LA)	32.16	0.30	1.21		24.642	0.450	2.311	1.201	1.924	0.866	-1596	-2613	1.32E-02	0.012
20150824@326.asc	SBB2015-2.5.6-1		33.56	0.30	2.57		26.031	0.522	2.518	1.193	2.110	0.950	-597	-2786	8.35E-03	0.007
20150824@327.asc	SBB2015-2.5.6-2	not used (no LA)	33.11	0.30	2.13		25.588	0.534	2.365	1.199	1.973	0.888	-725	-2670	8.59E-03	0.007
20150824@328.asc	SBB2015-2.5.6-3		33.21	0.30	2.23		25.688	0.515	2.503	1.197	2.091	0.941	-404	-2870	8.79E-03	0.007
20150824@329.asc	SBB2015-2.5.7-1		33.53	0.30	2.54		26.006	0.513	2.545	1.196	2.128	0.957	791	-2995	7.57E-03	0.006
20150824@330.asc	SBB2015-2.5.7-2		33.19	0.30	2.21		25.667	0.419	2.542	1.195	2.127	0.957	663	-2936	8.15E-03	0.007
20150824@331.asc	SBB2015-2.5.7-3		32.60	0.30	1.64		25.082	0.552	2.510	1.193	2.104	0.947	681	-2833	9.80E-03	0.008
20150824@332.asc	SBB2015-2.5.8-1		33.07	0.30	2.09		25.545	0.487	2.410	1.179	2.045	0.920	1995	-3007	1.09E-02	0.009
20150824@333.asc	SBB2015-2.5.8-2		32.86	0.30	1.89		25.343	0.460	2.392	1.177	2.033	0.915	2037	-3079	1.20E-02	0.010
20150824@334.asc	SBB2015-2.5.8-3		33.60	0.30	2.61		26.074	0.421	2.445	1.169	2.091	0.941	2109	-3284	8.72E-03	0.007
20150824@335.asc	SBB2015-UWC3-G1						5.274	0.467	2.572	1.163	2.213		-376	-77	1.51E-03	
20150824@336.asc	SBB2015-UWC3-G1						5.071	0.506	2.564	1.160	2.210		-409	-92	1.55E-03	
20150824@337.asc	SBB2015-UWC3-G1						5.386	0.524	2.650	1.206	2.197		-478	-11	1.51E-03	
20150824@338.asc	SBB2015-UWC3-G1						5.048	0.477	2.721	1.216	2.238		-564	-70	1.72E-03	
	bracket average and 2SD					-7.28	5.119	0.301			2.222				0.002	
	SBB2015-3															
20150824@339.asc	SBB2015-3-UWC3-G1						5.142	0.463	2.726	1.221	2.233		135	28	1.40E-03	
20150824@340.asc	SBB2015-3-UWC3-G1						5.115	0.436	2.724	1.218	2.236		105	24	1.43E-03	
20150824@341.asc	SBB2015-3-UWC3-G1						4.877	0.493	2.733	1.215	2.249		130	49	1.52E-03	
20150824@342.asc	SBB2015-3-UWC3-G1						5.216	0.487	2.720	1.214	2.241		158	41	1.47E-03	
	average and 2SD						5.088	0.293								
			VSMOW	2SD	VPDB											
20150824@343.asc	SBB2015-3.1.1-1	not used (no LA)	33.37	0.22	2.38		25.824	0.539	2.527	1.207	2.094	0.931	-4838	3608	1.08E-02	0.009
20150824@344.asc	SBB2015-3.1.1-2	not used (no LA)	32.14	0.22	1.19		24.604	0.799	2.437	1.210	2.014	0.896	-5007	3714	2.00E-02	0.019
20150824@345.asc	SBB2015-3.1.1-3	not used (no LA)	32.58	0.22	1.62		25.043	0.649	2.387	1.208	1.976	0.879	-5208	3928	1.05E-02	0.009
20150824@346.asc	SBB2015-3.1.2-1	not used (no LA)	33.15	0.22	2.17		25.610	0.489	2.618	1.211	2.163	0.962	-4109	3446	9.83E-03	0.008
20150824@347.asc	SBB2015-3.1.2-2	not used (no LA)	33.78	0.22	2.78		26.234	0.485	2.417	1.208	2.002	0.890	-4105	3583	7.60E-03	0.006
20150824@348.asc	SBB2015-3.1.2-3	not used (no LA)	33.57	0.22	2.58		26.029	0.571	2.483	1.197	2.074	0.923	-4007	3546	8.14E-03	0.007
20150824@349.asc	SBB2015-3.1.3-1		33.64	0.22	2.65		26.096	0.435	2.511	1.185	2.119	0.942	-3128	3807	8.21E-03	0.007
20150824@350.asc	SBB2015-3.1.3-2		33.33	0.22	2.35		25.787	0.462	2.529	1.178	2.147	0.955	-3210	3788	8.62E-03	0.007
20150824@351.asc	SBB2015-3.1.3-3	not used (no LA)	33.05	0.22	2.07		25.508	0.553	2.223	1.171	1.898	0.844	-3226	3913	1.20E-02	0.010
20150824@352.asc	SBB2015-3.1.4-1	not used (no LA)	33.15	0.22	2.18		25.613	0.728	2.113	1.169	1.807	0.804	-2494	4355	1.15E-02	0.010
20150824@353.asc	SBB2015-3.1.4-2	not used (no LA)	32.72	0.22	1.76		25.188	0.602	2.507	1.163	2.155	0.958	-2586	4282	1.00E-02	0.009
20150824@354.asc	SBB2015-3.1.4-3	not used (no LA)	33.48	0.22	2.49		25.933	0.542	2.489	1.155	2.154	0.958	-2277	4449	9.36E-03	0.008
20150824@355.asc	SBB2015-3-UWC3-G1;						5.222	0.557	2.589	1.150	2.251		218	94	1.58E-03	
20150824@356.asc	SBB2015-3-UWC3-G1;						5.088	0.430	2.588	1.145	2.262		276	8	1.54E-03	
20150824@357.asc	SBB2015-3-UWC3-G1;						5.058	0.588	2.574	1.143	2.251		283	-52	1.55E-03	
20150824@358.asc	SBB2015-3-UWC3-G1;						5.091	0.485	2.584	1.140	2.266		342	-41	1.56E-03	
	bracket average and 2SD					-7.30	5.101	0.217			2.249				0.002	
			VSMOW	2SD	VPDB											
20150824@359.asc	SBB2015-3.1.5-1;		33.21	0.30	2.23		25.772	0.522	2.470	1.130	2.185	0.964	-1332	3835	9.49E-03	0.008
20150824@360.asc	SBB2015-3.1.5-2;		33.76	0.30	2.76		26.310	0.553	2.442	1.128	2.166	0.956	-1564	3710	8.00E-03	0.006
20150824@361.asc	SBB2015-3.1.5-3;		33.53	0.30	2.54		26.086	0.529	2.460	1.128	2.180	0.962	-1412	3693	8.32E-03	0.007
20150824@362.asc	SBB2015-3.1.6-1		33.43	0.30	2.45		25.990	0.432	2.414	1.127	2.142	0.945	-571	3969	9.00E-03	0.007
20150824@363.asc	SBB2015-3.1.6-2;		33.58	0.30	2.59		26.137	0.400	2.333	1.123	2.077	0.917	-503	3980	8.09E-03	0.007
20150824@364.asc	SBB2015-3.1.6-3;		33.27	0.30	2.29		25.828	0.470	2.437	1.117	2.181	0.962	-739	3954	8.64E-03	0.007
20150824@365.asc	SBB2015-3.2.1-1;	unrelated analysis	33.67	0.30	2.68		26.229	0.557	2.507	1.163	2.156	0.951	-5439	2032	8.67E-03	0.007
20150824@366.asc	SBB2015-3.2.1-2;	unrelated analysis	33.35	0.30	2.36		25.903	0.545	2.519	1.162	2.168	0.957	-5267	2222	9.22E-03	0.008
20150824@367.asc	SBB2015-3.2.1-3;	unrelated analysis	33.47	0.30	2.48		26.023	0.508	2.499	1.158	2.158	0.952	-5199	2324	8.14E-03	0.007
20150824@368.asc	SBB2015-3.2.2-1;	unrelated analysis	30.35	0.30	-0.54		22.932	0.738	1.823	1.153	1.582	0.698	-4198	2301	1.45E-02	0.013
20150824@369.asc	SBB2015-3.2.2-2;	unrelated analysis	33.51	0.30	2.52		26.064	0.500	2.471	1.152	2.145	0.946	-4031	2277	8.67E-03	0.007
20150824@370.asc	SBB2015-3.2.2-3;	unrelated analysis	33.80	0.30	2.81		26.359	0.563	2.461	1.145	2.150	0.949	-3947	2311	9.39E-03	0.008
20150824@371.asc	SBB2015-3.2.2-4;	unrelated analysis	33.55	0.30	2.56		26.103	0.499	2.440	1.137	2.145	0.947	-3784	2336	9.70E-03	0.008

20150824@372.asc	SBB2015-3-UWC3-G1						5.428	0.574	2.564	1.127	2.275		29	-81	1.59E-03	
20150824@373.asc	SBB2015-3-UWC3-G1						5.272	0.535	2.561	1.123	2.281		73	-79	1.59E-03	
20150824@374.asc	SBB2015-3-UWC3-G1						5.378	0.435	2.615	1.149	2.275		99	-70	1.56E-03	
20150824@375.asc	SBB2015-3-UWC3-G1						5.046	0.493	2.673	1.177	2.271		209	-78	1.55E-03	
	bracket average and 2SD					-7.20	5.198	0.300			2.267				0.002	
			VSMOW	2SD	VPDB											
20150824@376.asc	SBB2015-3.2.3-1	unrelated analysis	33.04	0.39	2.07		25.541	0.550	2.304	1.182	1.949	0.861	-3108	2668	1.25E-02	0.011
20150824@377.asc	SBB2015-3.2.3-2	unrelated analysis	33.43	0.39	2.45		25.929	0.476	2.509	1.176	2.133	0.942	-3135	2398	9.39E-03	0.008
20150824@378.asc	SBB2015-3.2.3-3	unrelated analysis	33.59	0.39	2.59		26.081	0.512	2.514	1.171	2.148	0.949	-3125	2294	9.62E-03	0.008
20150824@379.asc	SBB2015-3.2.4-1	unrelated analysis	33.51	0.39	2.52		26.003	0.497	2.479	1.165	2.127	0.940	-2215	2947	9.41E-03	0.008
20150824@380.asc	SBB2015-3.2.4-2	unrelated analysis	33.61	0.39	2.62		26.104	0.523	2.500	1.162	2.151	0.950	-2151	2844	7.41E-03	0.006
20150824@381.asc	SBB2015-3.2.4-3	unrelated analysis	33.74	0.39	2.75		26.236	0.565	2.503	1.159	2.160	0.954	-2182	2749	7.41E-03	0.006
20150824@382.asc	SBB2015-3.2.5.1	unrelated analysis	33.02	0.39	2.05		25.520	0.522	2.505	1.155	2.169	0.958	-1335	2992	1.05E-02	0.009
20150824@383.asc	SBB2015-3.2.5.2	unrelated analysis	33.46	0.39	2.47		25.953	0.437	2.494	1.154	2.162	0.955	-1287	2888	9.49E-03	0.008
20150824@384.asc	SBB2015-3.2.5.3	unrelated analysis	33.47	0.39	2.48		25.968	0.518	2.503	1.149	2.177	0.962	-1301	2687	8.58E-03	0.007
20150824@385.asc	SBB2015-3.2.6-1	unrelated analysis	33.24	0.39	2.26		25.736	0.512	2.487	1.144	2.174	0.960	-403	2650	9.45E-03	0.008
20150824@386.asc	SBB2015-3.2.6-2	unrelated analysis	33.20	0.39	2.23		25.703	0.424	2.461	1.140	2.158	0.953	-307	2957	1.05E-02	0.009
20150824@387.asc	SBB2015-3.2.6-3	unrelated analysis	33.09	0.39	2.11		25.586	0.556	2.480	1.136	2.183	0.964	-376	3059	9.01E-03	0.007
20150824@388.asc	SBB2015-3-UWC3-G1						4.964	0.503	2.547	1.132	2.249		179	119	1.59E-03	
20150824@389.asc	SBB2015-3-UWC3-G1						4.890	0.504	2.549	1.129	2.256		202	181	1.57E-03	
20150824@390.asc	SBB2015-3-UWC3-G1						5.074	0.552	2.631	1.155	2.279		176	192	1.56E-03	
20150824@391.asc	SBB2015-3-UWC3-G1						5.061	0.468	2.625	1.179	2.228		215	251	1.59E-03	
	bracket average and 2SD					-7.26	5.139	0.393			2.264				0.002	
			VSMOW	2SD	VPDB											
20150824@392.asc	SBB2015-3.2.7-1;	unrelated analysis	33.76	0.29	2.76		26.113	0.494	2.538	1.173	2.164	0.957	627	3543	9.74E-03	0.008
20150824@393.asc	SBB2015-3.2.7-2;	unrelated analysis	33.73	0.29	2.73		26.083	0.535	2.535	1.178	2.152	0.952	775	3679	8.99E-03	0.007
20150824@394.asc	SBB2015-3.2.8-1;	unrelated analysis	32.42	0.29	1.46		24.783	0.649	2.393	1.177	2.033	0.899	1857	3688	1.23E-02	0.011
20150824@395.asc	SBB2015-3.2.8-2;	unrelated analysis	33.13	0.29	2.15		25.489	0.492	2.583	1.175	2.199	0.972	1704	3414	1.16E-02	0.010
20150824@396.asc	SBB2015-3.2.8-3;	unrelated analysis	28.77	0.29	-2.08		21.161	0.715	1.340	1.177	1.138	0.503	1392	2733	3.66E-02	0.035
20150824@397.asc	SBB2015-3.2.8-4;	unrelated analysis	33.36	0.29	2.38		25.722	0.514	2.356	1.177	2.002	0.885	1600	3155	1.15E-02	0.010
20150824@398.asc	SBB2015-3.2.8	unrelated analysis	33.70	0.29	2.71		26.061	0.505	2.509	1.174	2.137	0.945	1624	3905	8.68E-03	0.007
20150824@399.asc	SBB2015-3.2.8	unrelated analysis	33.08	0.29	2.10		25.438	0.474	2.573	1.172	2.196	0.971	1600	3813	9.68E-03	0.008
20150824@400.asc	SBB2015-3.2.8	unrelated analysis	33.51	0.29	2.52		25.867	0.472	2.541	1.167	2.176	0.962	1482	3894	9.42E-03	0.008
20150824@401.asc	SBB2015-3.2.9-1;	unrelated analysis	34.02	0.29	3.01		26.369	0.485	2.479	1.159	2.139	0.946	2956	3150	6.88E-03	0.005
20150824@402.asc	SBB2015-3.2.9-2;	unrelated analysis	32.32	0.29	1.37		24.686	0.734	1.835	1.157	1.587	0.702	2922	3571	1.14E-02	0.010
20150824@403.asc	SBB2015-3.2.9-3;	unrelated analysis	32.96	0.29	1.99		25.322	1.071	1.380	1.143	1.207	0.534	2894	3653	2.17E-02	0.020
20150824@404.asc	SBB2015-3.2.9-4;	unrelated analysis	34.16	0.29	3.15		26.510	0.542	2.438	1.143	2.133	0.944	2980	3216	7.03E-03	0.005
20150824@405.asc	SBB2015-3-UWC3-G1;						5.077	0.444	2.584	1.142	2.264		88	44	1.66E-03	
20150824@406.asc	SBB2015-3-UWC3-G1;						4.994	0.555	2.598	1.139	2.281		109	54	1.81E-03	
20150824@407.asc	SBB2015-3-UWC3-G1;						5.227	0.499	2.633	1.163	2.265		123	84	1.66E-03	
20150824@408.asc	SBB2015-3-UWC3-G1						4.738	0.472	2.692	1.187	2.267		142	93	1.66E-03	
	bracket average and 2SD					-7.39	5.003	0.291			2.261				0.002	
			VSMOW	2SD	VPDB											
20150824@409.asc	SBB2015-3.2.9	unrelated analysis	34.02	0.37	3.02		26.282	0.477	2.432	1.198	2.029	0.896	3105	3966	7.86E-03	0.006
20150824@410.asc	SBB2015-3.2.9	unrelated analysis	32.99	0.37	2.02		25.256	0.528	2.269	1.200	1.891	0.835	3044	4024	1.14E-02	0.010
20150824@411.asc	SBB2015-3.2.9	unrelated analysis	33.84	0.37	2.84		26.096	0.501	2.551	1.199	2.126	0.939	2981	3971	8.29E-03	0.007
20150824@412.asc	SBB2015-3.2.10-1	unrelated analysis	33.69	0.37	2.70		25.953	0.405	2.554	1.184	2.157	0.953	3605	3867	9.75E-03	0.008
20150824@413.asc	SBB2015-3.2.10-2	unrelated analysis	33.64	0.37	2.64		25.898	0.511	2.526	1.177	2.147	0.948	3534	3601	8.68E-03	0.007
20150824@414.asc	SBB2015-3.2.10-3	unrelated analysis	33.73	0.37	2.74		25.993	0.582	2.524	1.171	2.155	0.952	3462	3391	8.32E-03	0.007
20150824@415.asc	SBB2015-3.3.1-1		33.48	0.37	2.49		25.743	0.563	2.524	1.169	2.160	0.954	-4772	583	8.36E-03	0.007
20150824@416.asc	SBB2015-3.3.1-2		33.16	0.37	2.19		25.430	0.539	2.452	1.159	2.115	0.934	-4698	485	9.53E-03	0.008
20150824@417.asc	SBB2015-3.3.1-3		33.91	0.37	2.91		26.175	0.477	2.407	1.159	2.077	0.917	-4665	671	8.92E-03	0.007
20150824@418.asc	SBB2015-3.3.2-1		32.54	0.37	1.59		24.815	0.409	2.540	1.158	2.193	0.969	-3643	812	1.18E-02	0.010
20150824@419.asc	SBB2015-3-UWC3-G1						4.802	0.537	2.604	1.160	2.246		216	-4	1.58E-03	
20150824@420.asc	SBB2015-3-UWC3-G1						4.939	0.480	2.623	1.159	2.263		204	14	1.62E-03	
20150824@421.asc	SBB2015-3-UWC3-G1; Cs 215-216						4.672	0.449	2.696	1.184	2.277		226	80	1.58E-03	
20150824@422.asc	SBB2015-3-UWC3-G1;						4.836	0.481	2.727	1.212	2.250		230	100	1.63E-03	
	bracket average and 2SD					-7.49	4.911	0.370			2.264				0.002	
			VSMOW	2SD	VPDB											
20150824@423.asc	SBB2015-3.3.2-2		32.69	0.19	1.73		24.871	0.440	2.651	1.219	2.175	0.966	-3589	992	1.04E-02	0.009
20150824@424.asc	SBB2015-3.3.2-3	not used (no LA)	33.45	0.19	2.47		25.625	0.486	2.415	1.212	1.992	0.885	-3602	1176	9.52E-03	0.008
20150824@425.asc	SBB2015-3.3.3-1	not used (no LA)	32.51	0.19	1.55		24.683	0.638	1.964	1.192	1.647	0.731	-2650	1094	1.27E-02	0.011
20150824@426.asc	SBB2015-3.3.3-2	not used (no LA)	33.68	0.19	2.68		25.844	0.585	2.558	1.197	2.137	0.949	-2554	927	9.14E-03	0.008
20150824@427.asc	SBB2015-3.3.3-3	not used (no LA)	33.65	0.19	2.66		25.820	0.503	2.430	1.200	2.025	0.900	-2598	819	9.68E-03	0.008
20150824@428.asc	SBB2015-3.3.4-1	not used (no LA)	33.39	0.19	2.41		25.562	0.505	2.575	1.191	2.162	0.960	-1444	1357	1.01E-02	0.009
20150824@429.asc	SBB2015-3.3.4-2	not used (no LA)	33.37	0.19	2.39		25.545	0.428	2.554	1.194	2.139	0.950	-1453	1177	9.35E-03	0.008
20150824@430.asc	SBB2015-3.3.4-3	not used (no LA)	31.52	0.19	0.60		23.709	0.658	2.217	1.236	1.793	0.797	-1390	1092	1.28E-02	0.011
20150824@431.asc	SBB2015-3.3.4-4	not used (no LA)	32.77	0.19	1.80		24.941	0.494	2.553	1.255	2.035	0.904	-1397	1070	1.17E-02	0.010
20150824@432.asc	SBB2015-3-UWC3-G1						4.819	0.525	2.805	1.253	2.239		119	-90	1.52E-03	
20150824@433.asc	SBB2015-3-UWC3-G1						4.829	0.501	2.795	1.246	2.243		149	-82	1.51E-03	
20150824@434.asc	SBB2015-3-UWC3-G1						4.720	0.386	2.787	1.240	2.247		166	-66	1.55E-03	
20150824@435.asc	SBB2015-3-UWC3-G1						4.936	0.527	2.778	1.236	2.247		3	-84	1.49E-03	
	bracket average and 2SD					-7.58	4.819	0.185			2.252				0.002	
	8/26/2015															
	SBB2015-3															
20150824@436.asc	SBB2015-3-UWC3-G1						5.141	0.529	2.603	1.142	2.278		162	145	1.11E-03	
20150824@437.asc	SBB2015-3-UWC3-G1						5.227	0.503	2.591	1.138	2.276		145	138	1.19E-03	
20150824@438.asc	SBB2015-3-UWC3-G1						5.213	0.513	2.595	1.133	2.292		225	90	1.19E-03	
20150824@439.asc	SBB2015-3-UWC3-G1						4.929	0.497	2.682	1.169	2.294		254	97	1.08E-03	
	average and 2SD						5.128	0.275								
			VSMOW	2SD	VPDB											
20150824@440.asc	SBB2015-3.3.5-1		32.82	0.26	1.85		25.334	0.491	2.501	1.190	2.101	0.920	1122	1270	1.08E-02	0.010
20150824@441.asc	SBB2015-3.3.5-2		32.54	0.26	1.58		25.055	0.435	2.461	1.186	2.075	0.908	1161	1519	1.11E-02	0.010
20150824@442.asc	SBB2015-3.3.5-3		32.45	0.26	1.49		24.960	0.473	2.442	1.180	2.068	0.905	1205	1454	1.01E-02	0.009
20150824@443.asc	SBB2015-3.3.6-1	not used (no LA)	32.93	0.26	1.96		25.445	0.455	2.524	1.172	2.154	0.943	2411	1467	8.57E-03	0.007
20150824@444.asc	SBB2015-3.3.6-2	not used (no LA)	33.33	0.26	2.34		25.835	0.432	2.539	1.168	2.174	0.952	2451	1406	7.40E-03	0.006
20150824@445.asc	SBB2015-3.3.6-3	not used (no LA)	33.80	0.26	2.80		26.302	0.483	2.491	1.160	2.146	0.939	2444	1261	8.25E-03	0.007
20150824@446.asc	SBB2015-3.3.7-1		33.68	0.26	2.69		26.184	0.511	2.364	1.144	2.067	0.905	3642	1233	9.06E-03	0.008
20150824@447.asc	SBB2015-3.3.7-2	not used (no LA)	30.50	0.26	-0.40		23.031	0.634	2.254	1.150	1.959	0.857	3591	1017	1.30E-02	0.012
20150824@448.asc	SBB2015-3.3.7-3		33.49	0.26	2.51		26.000	0.388	2.481	1.138	2.180	0.954	3408	1684	9.17E-03	0.008
20150824@449.asc	SBB2015-3-UWC3-G1						5.195	0.517	2.593	1.133	2.288		73	73	1.22E-03	
20150824@450.asc	SBB2015-3-UWC3-G1						5.106	0.445	2.560	1.128	2.271		132	18	1.28E-03	
20150824@451.asc	SBB2015-3-UWC3-G1						5.348	0.446	2.667	1.164	2.290		166	87	1.25E-03	
20150824@452.asc	SBB2015-3-UWC3-G1						5.035	0.426	2.709	1.183	2.290		182	63	1.26E-03	
	bracket average and 2SD					-7.25	5.149	0.257			2.285				0.001	
			VSMOW	2SD	VPDB											
20150824@453.asc	SBB2015-3.3.8-1	not used (no LA)	33.50	0.28	2.51		25.939	0.426	2.505	1.180	2.123	0.930	4909	1338	8.26E-03	0.007
20150824@454.asc	SBB2015-3.3.8-2	not used (no LA)	33.46	0.28	2.47		25.897	0.599	2.391	1.186	2.016	0.883	4958	1353	9.52E-03	0.008
20150824@455.asc	SBB2015-3.3.8-3	not used (no LA)	32.77	0.28	1.80		25.209	0.543	2.328	1.180	1.973	0.864	4832	1477	1.12E-02	0.010
20150824@456.asc	SBB2015-3.4.1-1	not used (no LA)	30.86	0.28	-0.04		23.321	0.467	2.299	1.181	1.946	0.853	-5817	-2347	1.24E-02	0.011
20150824@457.asc	SBB2015-3.4.1-2		31.73	0.28	0.80		24.183	0.551	2.460	1.177	2.090	0.916	-5803	-2419	1.14E-02	0.010
20150824@458.asc	SBB2015-3.4.1-3		33.73	0.28	2.74		26.166	0.465	2.519	1.168	2.156	0.945	-5733	-2035	8.30E-03	0.007
20150824@459.asc	SBB2015-3.4.1-4		33.96	0.28	2.96		26.398	0.488	2.471	1.161	2.128	0.932	-5586	-2122	8.60E-03	0.007
20150824@460.asc	SBB2015-3.4.2-1	not used (no LA)	31.96	0.28	1.02		24.408	0.616	2.346	1.155	2.031	0.890	-4872	-2111	1.04E-02	0.009
20150824@461.asc	SBB2015-3.4.2-2	not used (no LA)	32.06	0.28	1.12		24.512	0.589	2.374	1.149	2.066	0.905	-4684	-2133	1.06E-02	0.009
20150824@462.asc	SBB2015-3.4.2-3	not used (no LA)	33.46	0.28	2.47		25.897	0.476	2.444	1.150	2.124	0.931	-4600	-2376	8.43E-03	0.007
20150824@463.asc	SBB2015-3.4.2-4	not used (no LA)	33.47	0.28	2.49		25.910	0.492	2.528	1.145	2.209	0.968	-4653	-2511	8.76E-03	0.008
20150824@464.asc	SBB2015-3.4.3-1		33.54	0.28	2.55		25.973	0.485	2.535	1.144	2.217	0.971	-3716	-2342	7.38E-03	0.006
20150824@465.asc	SBB2015-3-UWC3-G1;						5.083	0.541	2.595	1.144	2.269		112	-127	1.18E-03	
20150824@466.asc	SBB2015-3-UWC3-G1;						4.963	0.538	2.605	1.140	2.285		136	-163	1.18E-03	
20150824@467.asc	SBB2015-3-UWC3-G1;						4.917	0.493	2.578	1.135	2.272		279	-112	1.31E-03	
20150824@468.asc	SBB2015-3-UWC3-G1;						4.997	0.486	2.651	1.155	2.296		475	134	1.17E-03	
	bracket average and 2SD					-7.32	5.081	0.278			2.282				0.001	
			VSMOW	2SD	VPDB											
20150824@469.asc	SBB2015-3.4.3-2;		33.02	0.22	2.05		25.289	0.457	2.497	1.188	2.101	0.922	-3842	-2089	1.06E-02	0.009
20150824@470.asc	SBB2015-3.4.3-3	not used (construction vibration)	32.13	0.22	1.18		24.404	0.470	2.393	1.191	2.010	0.882	-3847	-2074	1.13E-02	0.010
20150824@471.asc	SBB2015-3.4.3-4;		33.74	0.22	2.74		26.002	0.448	2.514	1.190	2.112	0.927	-3565	-2235	7.35E-03	0.006
20150824@472.asc	SBB2015-3.4.4-1;	not used (no LA)	32.84	0.22	1.87		25.112	0.752	2.365	1.184	1.998	0.877	-2479	-2179	1.15E-02	0.010
20150824@473.asc	SBB2015-3.4.4-2;		33.14	0.22	2.17		25.411	0.472	2.585	1.178	2.193	0.963	-2273	-2278	9.48E-03	0.008
20150824@474.asc	SBB2015-3.4.4-3;		33.73	0.22	2.73		25.990	0.475	2.554	1.176	2.172	0.953	-2454	-1987	1.03E-02	0.009
20150824@475.asc	SBB2015-3.4.5-1;	not used (no LA)	24.34	0.22	-6.37		16.676	1.219	1.293	1.173	1.102	0.483	-985	-2230	1.97E-02	0.018
20150824@476.asc	SBB2015-3.4.5-2;		32.77	0.22	1.81		25.045	0.588	2.542	1.174	2.165	0.950	-1041	-2218	1.21E-02	0.011
20150824@477.asc	SBB2015-3.4.5-3;		33.20	0.22	2.22		25.466	0.510	2.493	1.180	2.112	0.927	-858	-2520	9.09E-03	0.008
20150824@478.asc	SBB2015-3.4.5-4;		32.87	0.22	1.90		25.138	0.422	2.494	1.180	2.114	0.928	-790	-2632	1.05E-02	0.009
20150824@479.asc	SBB2015-3-UWC3-G1;						4.726	0.477	2.706	1.179	2.295		42	23	1.21E-03	
20150824@480.asc	SBB2015-3-UWC3-G1;						4.815	0.512	2.695	1.187	2.270		176	19	1.33E-03	
20150824@481.asc	SBB2015-3-UWC3-G1;						4.931	0.492	2.740	1.201	2.282		245	29	1.29E-03	
20150824@482.asc	SBB2015-3-UWC3-G1;						4.864	0.564	2.714	1.201	2.260		252	69	1.31E-03	

	bracket average and 2SD					-7.48	4.912	0.221			2.279				0.001	
			VSMOW	2SD	VPDB											
20150824@483.asc	SBB2015-3.4.5-5		32.74	0.19	1.78		24.968	0.487	2.460	1.190	2.068	0.911	-911	-2737	1.26E-02	0.011
20150824@484.asc	SBB2015-3.4.5-6	not used (no LA)	7.60	0.19	-22.61		0.009	1.375	1.413	1.187	1.190	0.524	-891	-2680	4.67E-01	
20150824@485.asc	SBB2015-3.4.5-7	not used (no LA)	31.59	0.19	0.66		23.822	0.673	2.364	1.191	1.985	0.874	-927	-2690	1.17E-02	0.010
20150824@486.asc	SBB2015-3.4.6-1		33.45	0.19	2.47		25.672	0.497	2.597	1.192	2.179	0.960	189	-2582	8.07E-03	0.007
20150824@487.asc	SBB2015-3.4.6-2		33.53	0.19	2.54		25.748	0.500	2.613	1.189	2.198	0.968	182	-2382	8.23E-03	0.007
20150824@488.asc	SBB2015-3.4.6-3		33.27	0.19	2.29		25.488	0.418	2.516	1.192	2.110	0.930	139	-2174	7.89E-03	0.007
20150824@489.asc	SBB2015-3.4.7-1	not used (no LA)	33.74	0.19	2.75		25.959	0.487	2.570	1.200	2.141	0.943	1510	-2070	7.14E-03	0.006
20150824@490.asc	SBB2015-3.4.7-2	not used (no LA)	33.50	0.19	2.51		25.714	0.556	2.593	1.201	2.159	0.951	1563	-2131	7.85E-03	0.007
20150824@491.asc	SBB2015-3.4.7-3	not used (no LA)	32.84	0.19	1.87		25.065	0.607	2.540	1.207	2.105	0.927	1460	-2433	9.11E-03	0.008
20150824@492.asc	SBB2015-3.4.7-4	not used (no LA)	33.37	0.19	2.39		25.589	0.595	2.313	1.206	1.918	0.845	1427	-2385	1.03E-02	0.009
20150824@493.asc	SBB2015-3-UWC3-G1;						5.058	0.507	2.722	1.210	2.249		222	-80	1.26E-03	
20150824@494.asc	SBB2015-3-UWC3-G1;						4.822	0.490	2.760	1.215	2.271		237	-68	1.33E-03	
20150824@495.asc	SBB2015-3-UWC3-G1;						4.852	0.546	2.773	1.222	2.269		253	-59	1.38E-03	
20150824@496.asc	SBB2015-3-UWC3-G1;						4.860	0.470	2.768	1.223	2.264		329	-61	1.25E-03	
	bracket average and 2SD					-7.53	4.866	0.193			2.270				0.001	
			VSMOW	2SD	VPDB											
20150824@497.asc	SBB2015-3.4.8-1;		33.62	0.35	2.63		25.856	0.487	2.634	1.223	2.154	0.953	2573	-2132	8.49E-03	0.007
20150824@498.asc	SBB2015-3.4.8-2;		33.88	0.35	2.88		26.116	0.456	2.603	1.212	2.147	0.951	2657	-2039	9.23E-03	0.008
20150824@499.asc	SBB2015-3.4.8-3;		33.53	0.35	2.55		25.773	0.532	2.615	1.192	2.193	0.971	2458	-1838	8.66E-03	0.007
20150824@500.asc	SBB2015-3.5.1-1;	not used (no LA)	-24.77	0.35	-54.01		-32.090	6.139	0.075	1.186	0.063	0.028	-5645	-3368	1.20E-01	0.119
20150824@501.asc	SBB2015-3.5.1-2		34.40	0.35	3.39		26.636	0.490	2.518	1.187	2.122	0.939	-5649	-3348	7.44E-03	0.006
20150824@502.asc	SBB2015-3.5.1-3;		33.76	0.35	2.77		25.999	0.486	2.523	1.184	2.132	0.944	-5789	-3491	8.46E-03	0.007
20150824@503.asc	SBB2015-3.5.1-4;		33.88	0.35	2.88		26.119	0.403	2.560	1.196	2.140	0.947	-5841	-3576	9.61E-03	0.008
20150824@504.asc	SBB2015-3.5.2-1;		33.31	0.35	2.32		25.546	0.517	2.555	1.193	2.142	0.948	-4870	-3586	8.38E-03	0.007
20150824@505.asc	SBB2015-3.5.2-2;		33.37	0.35	2.39		25.611	0.418	2.564	1.194	2.148	0.951	-4788	-3659	8.83E-03	0.008
20150824@506.asc	SBB2015-3.5.2-3;	not used (no LA)	26.67	0.35	-4.11		18.965	5.397	2.121	1.197	1.772	0.784	-4647	-3771	9.15E-02	
20150824@507.asc	SBB2015-3.5.2-4;		34.16	0.35	3.15		26.391	0.453	2.521	1.205	2.093	0.927	-4752	-3453	7.44E-03	0.006
20150824@508.asc	SBB2015-3.5.3-1;	not used (no LA)	30.79	0.35	-0.12		23.051	0.673	1.410	1.207	1.168	0.517	-3621	-3539	1.73E-02	0.016
20150824@509.asc	SBB2015-3.5.3-2;		33.13	0.35	2.15		25.368	0.458	2.549	1.209	2.109	0.934	-3631	-3560	1.02E-02	0.009
20150824@510.asc	SBB2015-3-UWC3-G1;						5.012	0.470	2.757	1.213	2.273		161	-9	1.35E-03	
20150824@511.asc	SBB2015-3-UWC3-G1;						4.642	0.498	2.742	1.217	2.253		390	44	1.23E-03	
20150824@512.asc	SBB2015-3-UWC3-G1;						4.702	0.518	2.745	1.218	2.254		405	14	1.24E-03	
20150824@513.asc	SBB2015-3-UWC3-G1						5.149	0.412	2.724	1.217	2.238		285	24	1.34E-03	
	bracket average and 2SD					-7.51	4.887	0.350			2.259				0.001	
			VSMOW	2SD	VPDB											
20150824@514.asc	SBB2015-3.5.3-3;	not used (no LA)	18.30	0.44	-12.23		10.731	2.060	0.282	1.208	0.233	0.103	-3512	-3514	4.54E-02	0.043
20150824@515.asc	SBB2015-3.5.3-4;		33.63	0.44	2.64		25.945	0.464	2.665	1.215	2.193	0.971	-3526	-3503	8.47E-03	0.007
20150824@516.asc	SBB2015-3.5.3-5;	not used (no LA)	33.27	0.44	2.29		25.587	0.516	2.614	1.217	2.147	0.951	-3421	-3638	8.60E-03	0.007
20150824@517.asc	SBB2015-3.5.4-1;	not used (no LA)	33.56	0.44	2.58		25.883	0.468	2.665	1.223	2.179	0.965	-2248	-3727	7.63E-03	0.006
20150824@518.asc	SBB2015-3.5.4-2;	not used (no LA)	34.16	0.44	3.15		26.475	0.517	2.517	1.194	2.109	0.934	-2077	-3878	7.76E-03	0.006
20150824@519.asc	SBB2015-3.5.4-3;	not used (no LA)	35.00	0.44	3.97		27.310	0.453	2.167	1.185	1.828	0.810	-2032	-4004	8.04E-03	0.006
20150824@520.asc	SBB2015-3.5.5-1;		32.78	0.44	1.82		25.107	0.536	2.460	1.153	2.134	0.945	-1206	-4075	1.05E-02	0.009
20150824@521.asc	SBB2015-3.5.5-2;		32.77	0.44	1.80		25.092	0.475	2.416	1.148	2.105	0.932	-991	-3897	8.84E-03	0.007
20150824@522.asc	SBB2015-3.5.5-3;		33.21	0.44	2.23		25.534	0.564	2.539	1.154	2.201	0.975	-1195	-4207	7.95E-03	0.006
20150824@523.asc	SBB2015-3.5.6-1;		33.07	0.44	2.10		25.397	0.496	2.467	1.152	2.143	0.949	30	-4151	1.03E-02	0.008
20150824@524.asc	SBB2015-3.5.6-2;		33.25	0.44	2.27		25.574	0.679	2.439	1.156	2.110	0.935	-128	-4193	1.07E-02	0.009
20150824@525.asc	SBB2015-3.5.6-3		33.49	0.44	2.50		25.809	0.429	2.518	1.164	2.162	0.958	81	-4059	8.46E-03	0.007
20150824@526.asc	SBB2015-3.5.7-1;		33.61	0.44	2.62		25.931	0.489	2.534	1.164	2.177	0.965	995	-4045	9.54E-03	0.008
20150824@527.asc	SBB2015-3-UWC3-G1						5.305	0.592	2.582	1.155	2.236		307	199	6.10E-03	
20150824@528.asc	SBB2015-3-UWC3-G1						4.944	0.526	2.604	1.150	2.264		397	212	1.27E-03	
20150824@529.asc	SBB2015-3-UWC3-G1; Cs 217-218						5.037	0.500	2.702	1.189	2.273		399	239	1.24E-03	
20150824@530.asc	SBB2015-3-UWC3-G1;						4.929	0.482	2.743	1.209	2.269		458	219	1.24E-03	
	bracket average and 2SD					-7.43	4.965	0.436			2.257				0.002	
			VSMOW	2SD	VPDB											
20150824@531.asc	SBB2015-3.5.7-2 ;		33.37	0.26	2.38		25.766	0.566	2.652	1.215	2.183	0.962	1032	-3926	8.96E-03	0.007
20150824@532.asc	SBB2015-3.5.7-3;	not used (no LA)	33.45	0.26	2.47		25.851	0.471	2.633	1.208	2.180	0.961	976	-3748	8.76E-03	0.007
20150824@533.asc	SBB2015-3.5.8.1;		33.31	0.26	2.33		25.709	0.464	2.617	1.219	2.147	0.946	2348	-4064	8.45E-03	0.007
20150824@534.asc	SBB2015-3.5.8.2;		33.27	0.26	2.29		25.670	0.605	2.561	1.209	2.118	0.933	2147	-3773	9.31E-03	0.007
20150824@535.asc	SBB2015-3.5.8.3;	not used (no LA)	33.59	0.26	2.60		25.984	0.445	2.605	1.199	2.173	0.957	2263	-3899	8.48E-03	0.007
20150824@536.asc	SBB2015-3.5.9-1;		33.53	0.26	2.54		25.923	0.469	2.631	1.196	2.200	0.969	3301	-3718	9.00E-03	0.007
20150824@537.asc	SBB2015-3.5.9-2;	not used (no LA)	33.23	0.26	2.25		25.628	0.448	2.668	1.200	2.222	0.979	3352	-3716	7.92E-03	0.006
20150824@538.asc	SBB2015-3.5.9-3;		33.55	0.26	2.56		25.950	0.493	2.626	1.207	2.176	0.959	3366	-3550	8.48E-03	0.007
20150824@539.asc	SBB2015-3.5.10-1;	not used (no LA)	33.49	0.26	2.50		25.886	0.443	2.605	1.197	2.176	0.959	4421	-3832	7.85E-03	0.006
20150824@540.asc	SBB2015-3.5.10-2;	not used (no LA)	33.77	0.26	2.77		26.164	0.530	2.451	1.197	2.048	0.903	4343	-3908	9.42E-03	0.007
20150824@541.asc	SBB2015-3.5.10-3;	not used (no LA)	33.61	0.26	2.62		26.002	0.488	2.543	1.176	2.163	0.953	4394	-3716	7.55E-03	0.006
20150824@542.asc	SBB2015-3.6.1-1;		33.94	0.26	2.93		26.329	0.490	2.493	1.149	2.170	0.956	-200	-5406	8.05E-03	0.006
20150824@543.asc	SBB2015-3.6.1-2;		33.74	0.26	2.75		26.139	0.406	2.431	1.149	2.116	0.932	-243	-5457	7.91E-03	0.006
20150824@544.asc	SBB2015-3.6.1-3;	not used (no LA)	33.73	0.26	2.73		26.124	0.543	2.284	1.150	1.985	0.875	-141	-5654	8.84E-03	0.007
20150824@545.asc	SBB2015-3-UWC3-G1						5.043	0.475	2.620	1.148	2.283		61	91	1.39E-03	
20150824@546.asc	SBB2015-3-UWC3-G1						4.947	0.437	2.605	1.145	2.276		100	112	1.41E-03	
20150824@547.asc	SBB2015-3-UWC3-G1						4.977	0.491	2.605	1.143	2.280		44	10	1.38E-03	
20150824@548.asc	SBB2015-3-UWC3-G1						5.147	0.507	2.593	1.140	2.275		58	-3	1.42E-03	
	bracket average and 2SD					-7.36	5.041	0.257			2.269				0.002	

Conversion of the standard reference: d18OVPDB = (d18OVSMOW - 30.91)/1.03091 from: Coplen, T. B., Kendall, C., and Hopple, J., 1983. Comparison of stable isotope reference samples. Nature 302, 236-238.

All values of δ18O, were calculated on the VSMOW scale established by the UWC-3 bracketing standard. The external precision for d18OVSMOW measurements is reported as 2 times the standard deviation of typically 8 bracketing UWC-3 calcite standard analyses.

beam off: electron flood gun inadvertently left off, analysis discarded; not used (no LA): this analysis has been discarded because there is no corresponding Laser Ablation analysis; unrelated analysis: analysis on foraminifera not belonging to the Genus Uvigerina, analysis discarded.

Appendix B: Bulk analysis data. The asterisks represent data already reported in Balestra et al., (2018)

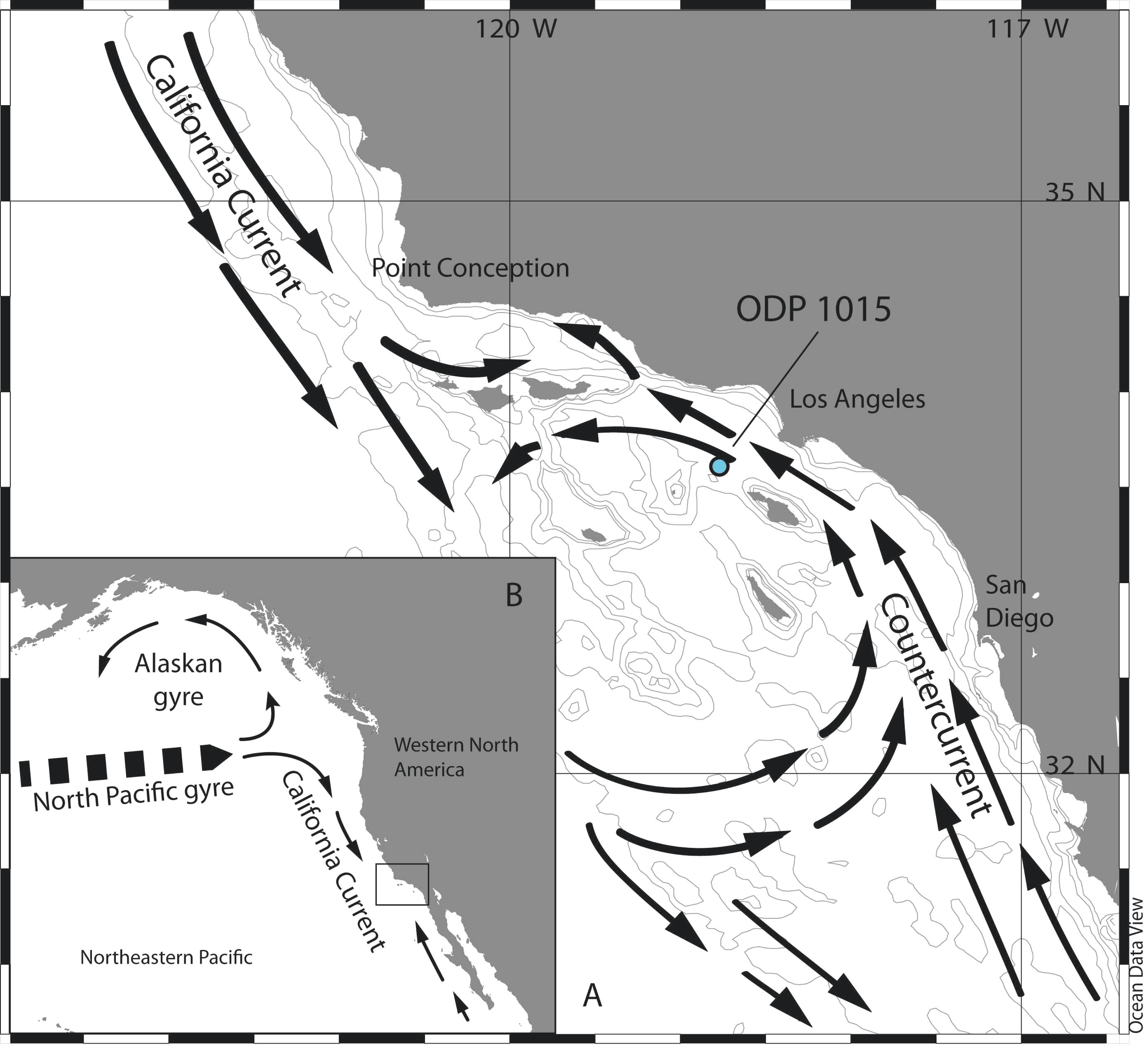
age cal. y.b.p.	Mg/Ca (mmol/mol)	Sr/Ca (mmol/mol)	Mass Bias (‰) PDB
197	0.67	1.25	2.82
561	1.01	1.26	2.80*
1003	0.42	1.20	2.96
12115	0.86	1.32	3.09
12463	1.65	1.26	3.24*
12976	0.58	1.26	3.43

Appendix C: 12 µm spots for LA-ICP results.								
					Average for each tests		Average for each time slice	
Age cal. y.b.p.	# Chambers	Foraminifera #	Mg/Ca (LA)	Sr/Ca (LA)	Mg/Ca (LA)	Sr/Ca (LA)	Mg/Ca (LA)	Sr/Ca (LA)
197	1	1	0.95	1.36	1.19	1.28	1.00	1.25
197	3	1	1.58	1.30				
197	5	1	0.72	1.29				
197	6	1	1.50	1.19				
197	6	2	0.76	1.27	0.94	1.21		
197	5	2	0.64	1.18				
197	7	2	1.43	1.17				
197	8	3	0.85	1.19	0.89	1.23		
197	6	3	0.92	1.27				
197	5	4	0.62	1.32	0.62	1.34		
197	4	4	0.66	1.33				
197	5	4	0.58	1.35				
197	3	5	1.63	1.20	1.38	1.21		
197	3	5	1.54	1.27				
197	4	5	0.98	1.15				
561	2	6	0.73	1.22	0.67	1.21	0.99	1.27
561	4	6	0.68	1.22				
561	5	6	0.61	1.18				
561	3	7	1.44	1.35	1.21	1.33		
561	6	7	0.98	1.30				
561	4	8	1.04	1.36	0.80	1.26		
561	7	8	0.55	1.14				
561	8	8	0.81	1.29				
561	5	9	0.88	1.29	1.09	1.36		
561	4	9	1.30	1.42				
561	6	10	1.28	1.17	1.06	1.22		
561	5	10	0.84	1.26				
561	1	11	1.09	1.26	1.12	1.24		
561	2	11	0.90	1.27				
561	3	11	0.92	1.25				
561	7	11	0.92	1.29				
561	7	11	2.14	1.15				
561	8	11	0.77	1.19				
1003	5	12	0.59	1.23	0.86	1.14	0.84	1.20
1003	7	12	1.12	1.05				
1003	4	13	0.63	1.21	0.64	1.17		
1003	5	13	0.76	1.15				
1003	6	13	0.54	1.16				
1003	4	14	0.65	1.25	0.68	1.21		
1003	6	14	0.70	1.17				
1003	5	15	0.55	1.21	1.26	1.26		
1003	4	15	2.28	1.30				
1003	3	15	0.96	1.27				
1003	1	16	0.70	1.24	0.75	1.24		
1003	6	16	0.76	1.32				
1003	8	16	0.79	1.16				
12115	3	17	0.99	1.36	0.93	1.34	0.90	1.32
12115	1	17	1.13	1.39				
12115	6	17	0.68	1.26				
12115	1	18	0.84	1.22	0.86	1.28		
12115	4	18	0.89	1.34				
12115	3	19	0.74	1.31	0.89	1.34		

12115	7	19	0.72	1.47				
12115	5	19	1.23	1.25				
12463	4	20	1.54	1.40	1.47	1.32	1.15	1.24
12463	5	20	1.20	1.23				
12463	6	20	1.65	1.34				
12463	4	22	0.94	1.27	1.07	1.26		
12463	6	22	1.20	1.25				
12463	6	23	1.95	1.20	1.41	1.21		
12463	7	23	1.13	1.18				
12463	8	23	1.16	1.25				
12463	5	24	1.90	1.16	1.25	1.23		
12463	10	24	0.60	1.29				
12463	3	25	1.05	1.09	1.55	1.15		
12463	7	25	1.44	1.21				
12463	8	25	2.15	1.16				
12463	1	26	0.85	1.25	0.92	1.23		
12463	5	26	1.36	1.22				
12463	7	26	0.55	1.22				
12463	5	27	0.43	1.15	0.71	1.17		
12463	8	27	0.99	1.19				
12463	7	28	0.93	1.30	0.97	1.33		
12463	7	28	1.14	1.44				
12463	10	28	1.03	1.32				
12463	12	28	0.77	1.25				
12463	1	29	0.81	1.25	1.00	1.30		
12463	6	29	1.17	1.38				
12463	7	29	1.01	1.28				
12463	7	30	1.74	1.39	1.14	1.24		
12463	8	30	0.74	1.23				
12463	10	30	0.96	1.11				
12976	1	31	1.04	1.40	0.84	1.33	0.83	1.27
12976	5	31	0.83	1.31				
12976	8	31	0.64	1.29				
12976	5	32	0.59	1.29	0.55	1.29		
12976	6	32	0.54	1.29				
12976	3	32	0.54	1.30				
12976	7	33	0.61	1.34	0.73	1.23		
12976	6	33	0.86	1.13				
12976	2	34	0.77	1.22	1.02	1.18		
12976	4	34	1.04	1.18				
12976	6	34	1.26	1.13				
12976	5	35	0.63	1.19	0.61	1.26		
12976	4	35	0.62	1.36				
12976	6	35	0.58	1.23				
12976	9	36	0.69	1.27	0.70	1.23		
12976	2	36	0.71	1.20				
12976	2	37	1.04	1.18	0.86	1.21		
12976	8	37	0.69	1.23				
12976	6	38	0.77	1.38	1.23	1.34		
12976	7	38	1.69	1.29				
12976	5	39	0.65	1.42	0.92	1.33		
12976	1	39	1.19	1.25				

Appendix D: 50 µm spots for LA-ICP results.					average each test		average each time period	
# test	age cal. Y.b.p.	Mg/Ca	Sr/Ca	Mn/Ca	Mg/Ca	Sr/Ca	Mg/Ca	Sr/Ca
1	197	1.21	1.15	0.0015	1.21	1.21	1.13	1.23
	197	0.94	1.16	0.0014				
	197	1.21	1.27	0.0009				
	197	1.48	1.26	0.0036				
2	197	1.44	1.31	0.0088	1.63	1.24		
	197	1.83	1.23	0.0028				
	197	1.67	1.23	0.0012				
	197	1.60	1.18	0.0028				
3	197	1.07	1.31	0.0166	1.57	1.22		
	197	1.21	1.16	0.0015				
	197	1.33	1.21	0.0013				
	197	2.66	1.18	0.0025				
4	197	1.23	1.28	-0.0105	0.99	1.25		
	197	1.19	1.31	0.0028				
	197	0.82	1.20	0.0016				
	197	0.72	1.20	0.0018				
5	197	1.29	1.40	0.0031	1.08	1.30		
	197	0.96	1.27	0.0024				
	197	0.98	1.24	0.0021				
	197	1.08	1.28	0.0104				
6	197	0.45	1.18	0.0020	0.61	1.21		
	197	0.41	1.18	0.0004				
	197	0.65	1.26	0.0022				
	197	0.68	1.16	0.0017				
	197	0.88	1.26	0.0050				
7	197	1.51	1.34	0.0036	0.82	1.19		
	197	0.60	1.18	0.0011				
	197	0.57	1.18	0.0034				
	197	0.60	1.07	0.0029				
8	561	1.76	1.32	0.0044	1.96	1.46	1.35	1.23
	561	2.14	1.52	0.0044				
	561	2.32	1.54	0.0034				
	561	1.61	1.44	0.0031				
9	561	1.28	1.13	0.0049	1.06	1.13		
	561	1.27	1.11	0.0041				
	561	0.93	1.13	0.0024				
	561	0.75	1.13	0.0013				
10	561	1.17	1.32	0.0036	0.96	1.21		
	561	1.09	1.24	0.0015				
	561	0.81	1.14	0.0011				
	561	0.79	1.13	0.0036				
11	561	0.66	1.33	0.0002	1.13	1.25		
	561	1.81	1.34	0.0031				
	561	1.35	1.24	0.0023				
	561	0.70	1.10	0.0014				
12	561	0.96	1.11	0.0046	1.25	1.18		
	561	1.21	1.16	0.0033				
	561	1.22	1.16	0.0036				
	561	1.62	1.27	0.0038				
13	561	1.49	1.35	0.0020	1.48	1.29		
	561	1.95	1.33	0.0028				
	561	1.40	1.28	0.0018				
	561	1.07	1.20	0.0011				
14	561	1.00	1.08	0.0038	1.18	1.14		
	561	0.96	1.10	0.0036				
	561	1.02	1.12	0.0023				
	561	1.73	1.25	0.0032				

15	561	1.18	1.33	0.0019	1.13	1.23		
	561	1.29	1.24	0.0015				
	561	0.98	1.18	0.0016				
	561	1.08	1.18	0.0015				
16	561	3.19	1.32	0.0026	2.00	1.20		
	561	1.92	1.16	0.0037				
	561	2.35	1.14	0.0029				
	561	2.03	1.17	0.0029				
17	1003	1.42	1.33	0.0055	1.22	1.28	1.41	1.25
	1003	1.15	1.30	0.0037				
	1003	1.45	1.24	0.0025				
	1003	0.85	1.23	0.0027				
18	1003	2.47	1.38	0.0058	1.60	1.22		
	1003	1.37	1.22	0.0047				
	1003	1.13	1.11	0.0071				
	1003	1.43	1.16	0.0060				
19	12115	1.16	1.37	0.0168	1.43	1.36	1.57	1.27
	12115	1.56	1.35	0.0146				
	12115	1.58	1.35	0.0160				
20	12115	1.80	1.19	0.0155	1.70	1.19		
	12115	1.58	1.23	0.0178				
	12115	1.73	1.16	0.0199				
21	12463	1.10	1.28	0.0158	1.29	1.17	1.12	1.19
	12463	1.36	1.22	0.0183				
	12463	0.93	1.15	0.0142				
	12463	1.79	1.04	0.0263				
22	12463	0.95	1.35	0.0106	0.91	1.27		
	12463	1.08	1.43	0.0125				
	12463	0.95	1.18	0.0127				
	12463	0.68	1.13	0.0080				
23	12463	0.79	1.09	0.0203	1.19	1.19		
	12463	1.61	1.17	0.0149				
	12463	1.11	1.22	0.0232				
	12463	0.84	1.20	0.0152				
24	12463	0.80	1.19	0.0099	0.92	1.18		
	12463	0.90	1.17	0.0086				
	12463	1.07	1.17	0.0123				
25	12463	1.35	1.15	0.0190	1.28	1.17		
	12463	0.77	1.21	0.0145				
	12463	0.90	1.18	0.0152				
	12463	2.24	1.16	0.0408				
	12463	1.12	1.13	0.0144				
26	12463	0.79	1.15	0.0169	0.82	1.10		
	12463	0.94	1.13	0.0234				
	12463	0.73	1.11	0.0150				
	12463	0.74	1.08	0.0149				
	12463	0.92	1.04	0.0171				
27	12463	1.26	1.19	0.0117	1.39	1.21		
	12463	0.93	1.24	0.0104				
	12463	1.98	1.19	0.0127				
28	12976	1.61	1.11	0.1224	1.71	1.08	1.51	1.15
	12976	1.39	1.08	0.0655				
	12976	2.73	1.07	0.0852				
	12976	1.11	1.05	0.0536				
29	12976	1.06	1.24	0.0911	1.30	1.22		
	12976	1.59	1.25	0.1474				
	12976	1.28	1.24	0.0981				
	12976	1.29	1.17	0.0525				



120 W
117 W
35 N
32 N
California Current
Point Conception
ODP 1015
Los Angeles
San Diego
Countercurrent
B
Alaskan gyre
Western North America
North Pacific gyre
California Current
Northeastern Pacific
A
Ocean Data View

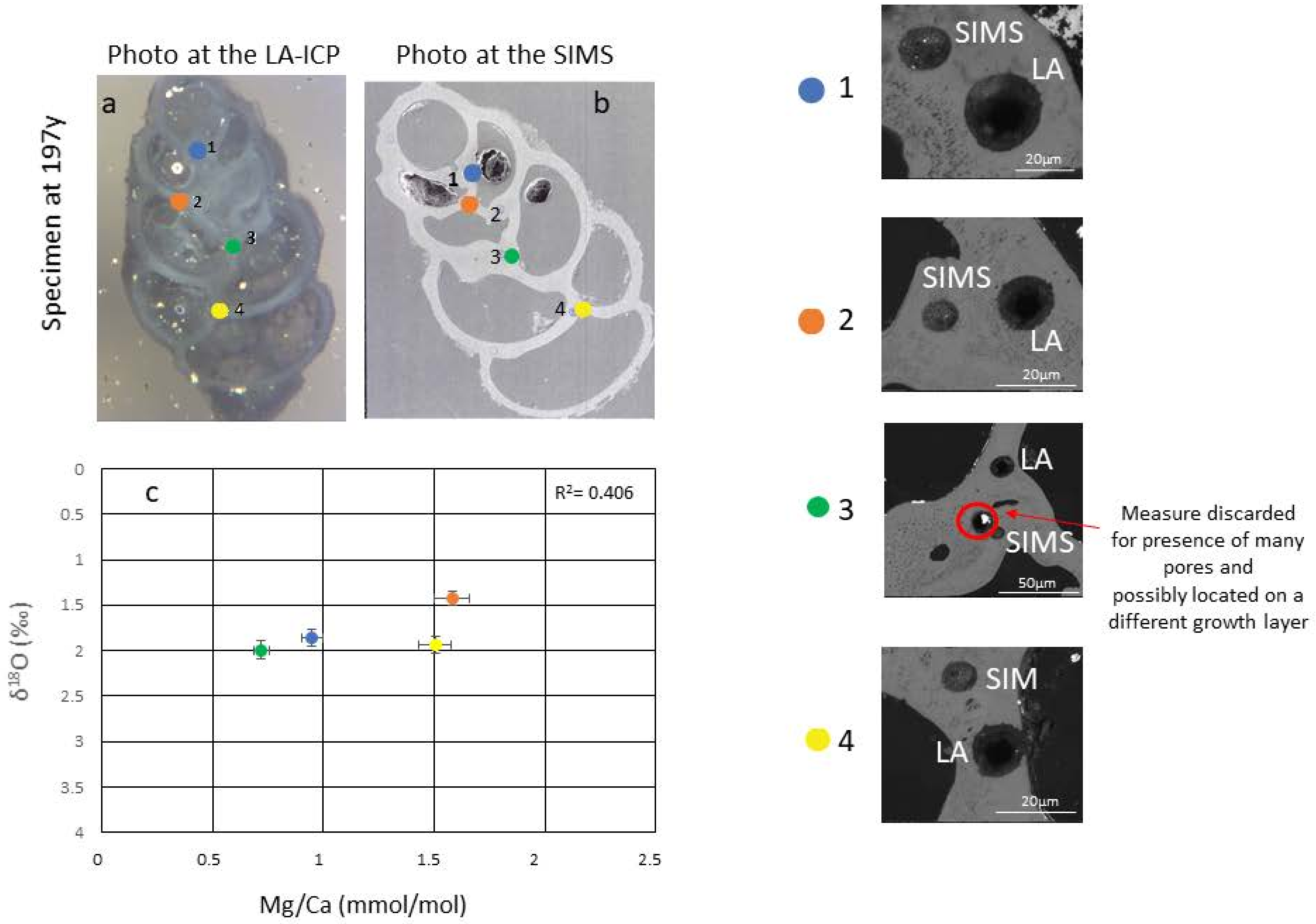


Photo at the LA-ICP
Photo at the SIMS
Specimen at 197y
a
b
1
2
3
4
c
R²= 0.406
δ18O (‰)
Mg/Ca (mmol/mol)
SIMS
LA
20µm
50µm
SIM
Measure discarded for presence of many pores and possibly located on a different growth layer

Figure 2

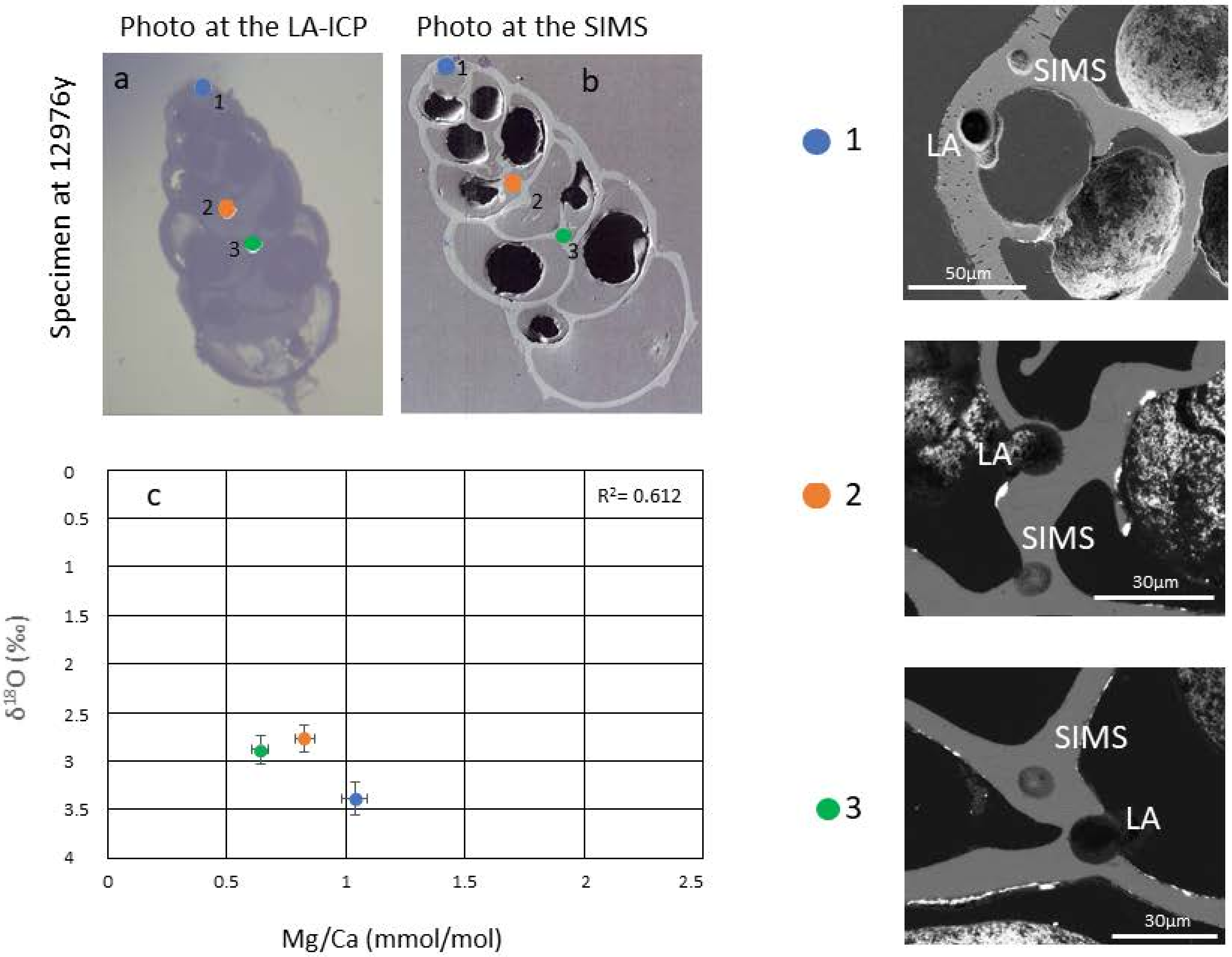


Photo at the LA-ICP
Photo at the SIMS
Specimen at 12976y
a
b
1
2
3
c
R²= 0.612
δ18O (‰)
Mg/Ca (mmol/mol)
0
0.5
1
1.5
2
2.5
3
3.5
4
0
0.5
1
1.5
2
2.5
SIMS
LA
50µm
30µm

Figure 3

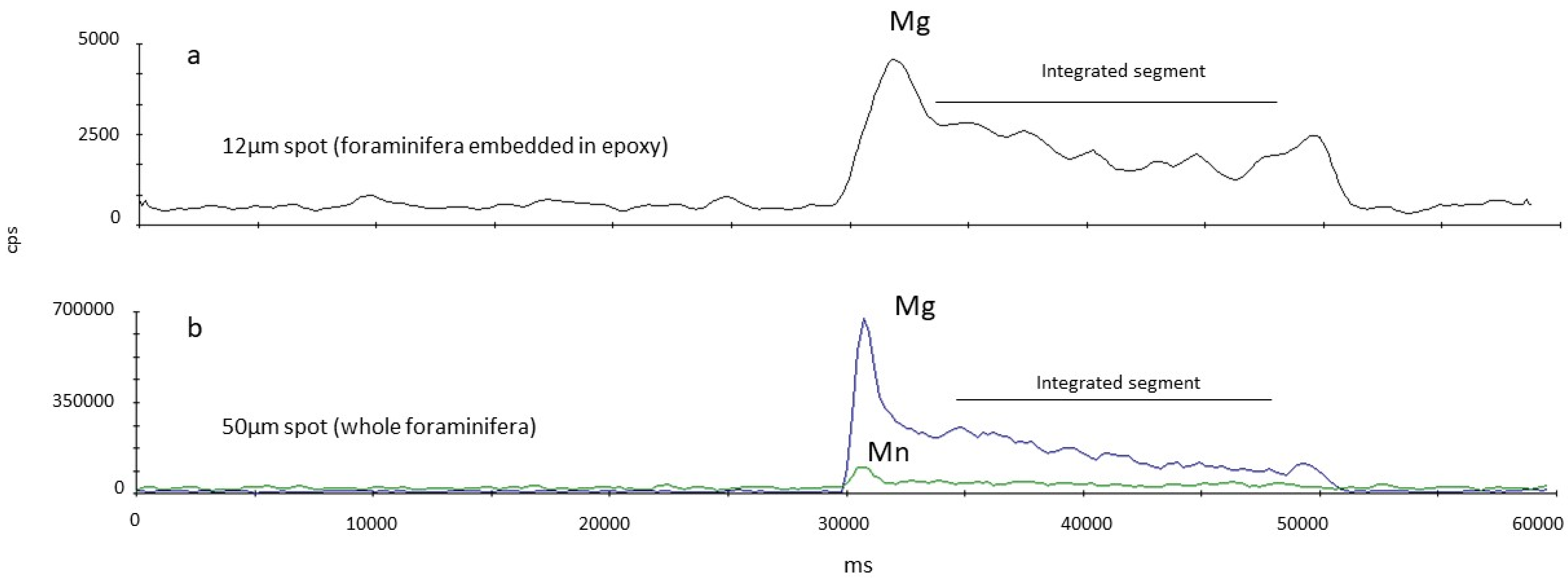

Mg
5000
a
Integrated segment
2500
12µm spot (foraminifera embedded in epoxy)
0
cps
700000
b
Mg
Integrated segment
350000
50µm spot (whole foraminifera)
Mn
0
0
10000
20000
30000
40000
50000
60000
ms

Figure 4

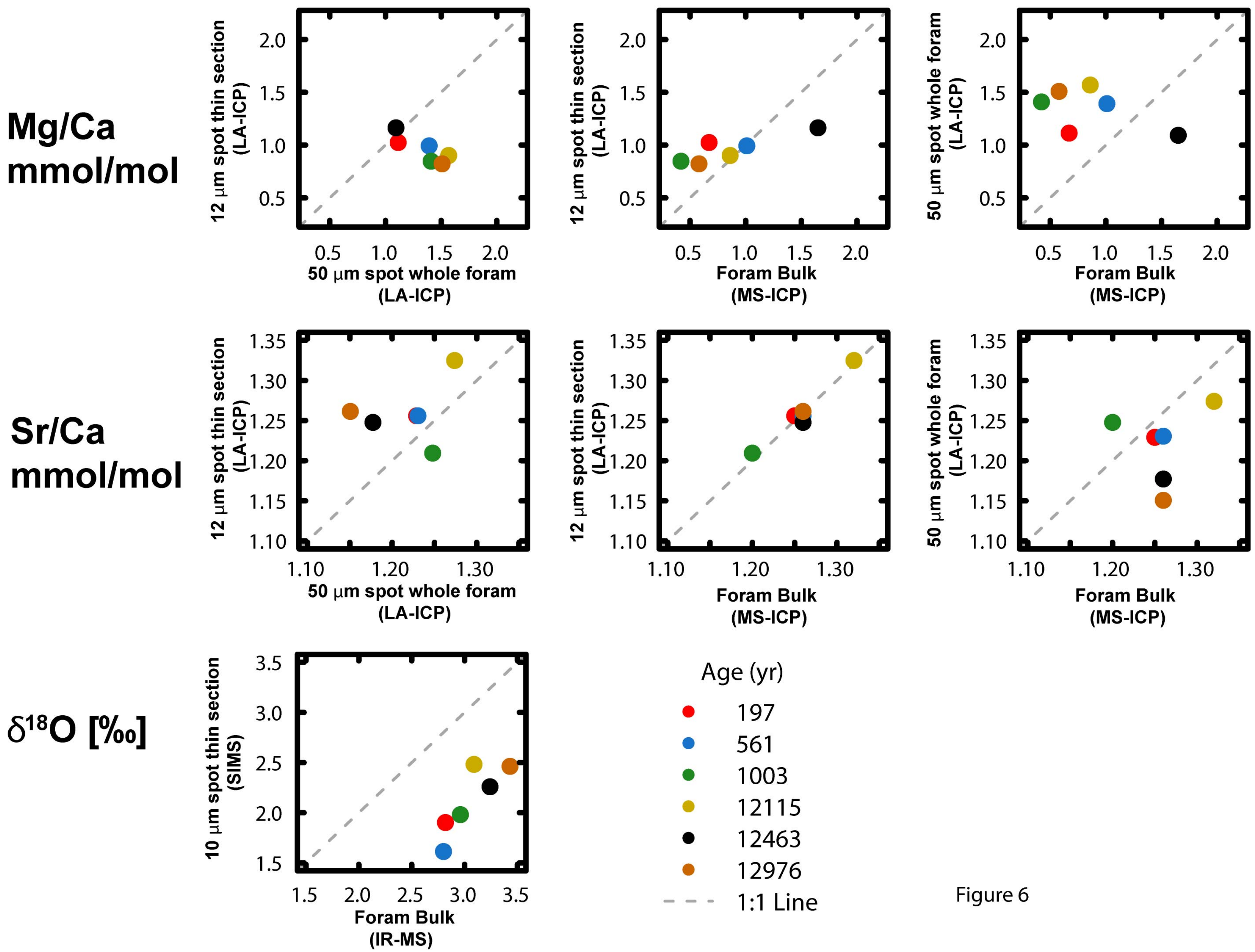

Mg/Ca mmol/mol
Sr/Ca mmol/mol
δ18O [‰]
12 μm spot thin section (LA-ICP)
50 μm spot whole foram (LA-ICP)
Foram Bulk (MS-ICP)
10 μm spot thin section (SIMS)
Foram Bulk (IR-MS)
Age (yr)
197
561
1003
12115
12463
12976
1:1 Line

Figure 6

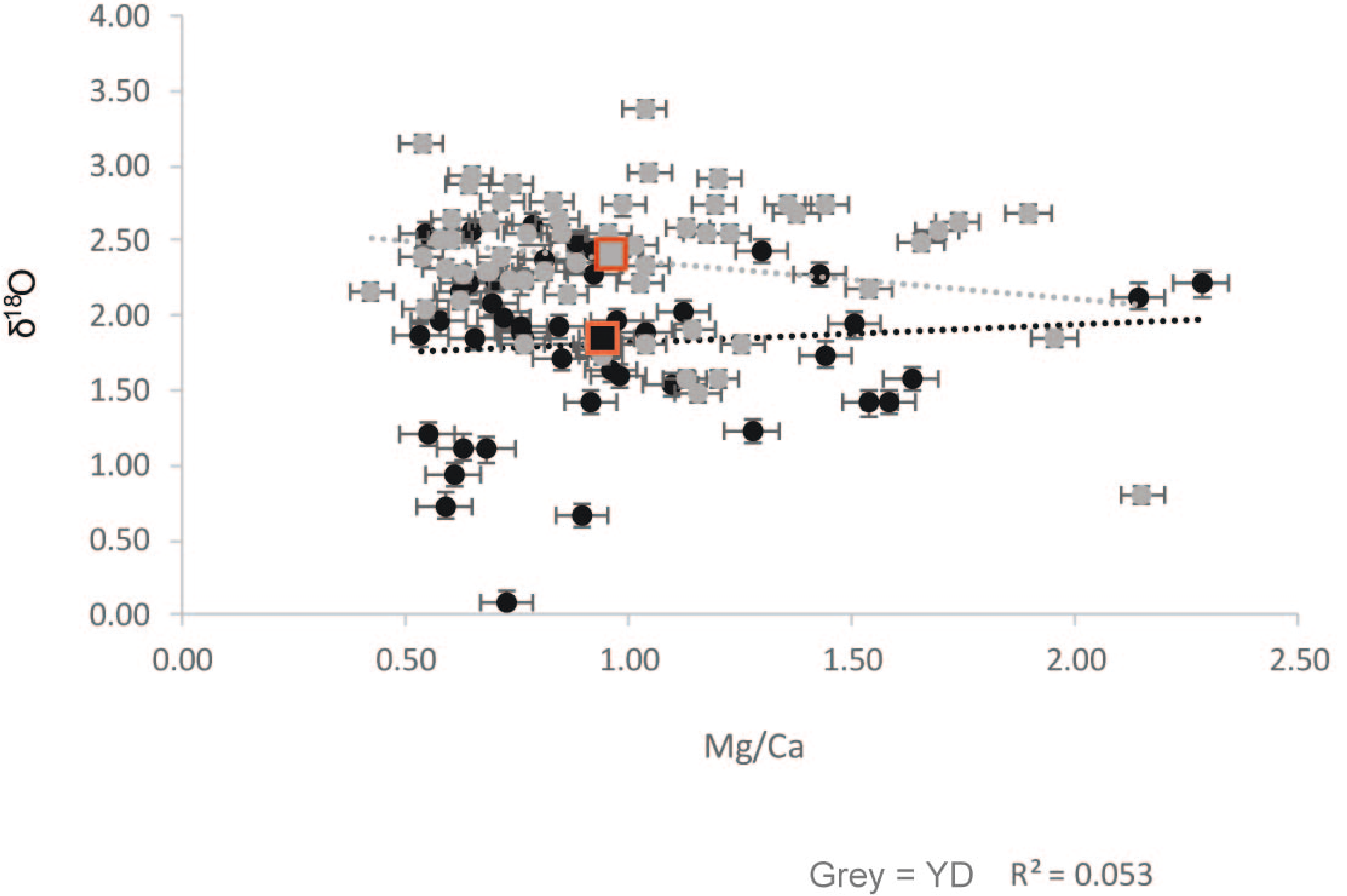

4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
δ18O
0.00
0.50
1.00
1.50
2.00
2.50
Mg/Ca
Grey = YD R2 = 0.053
Black = Holocene R2 = 0.0076

Figure 7

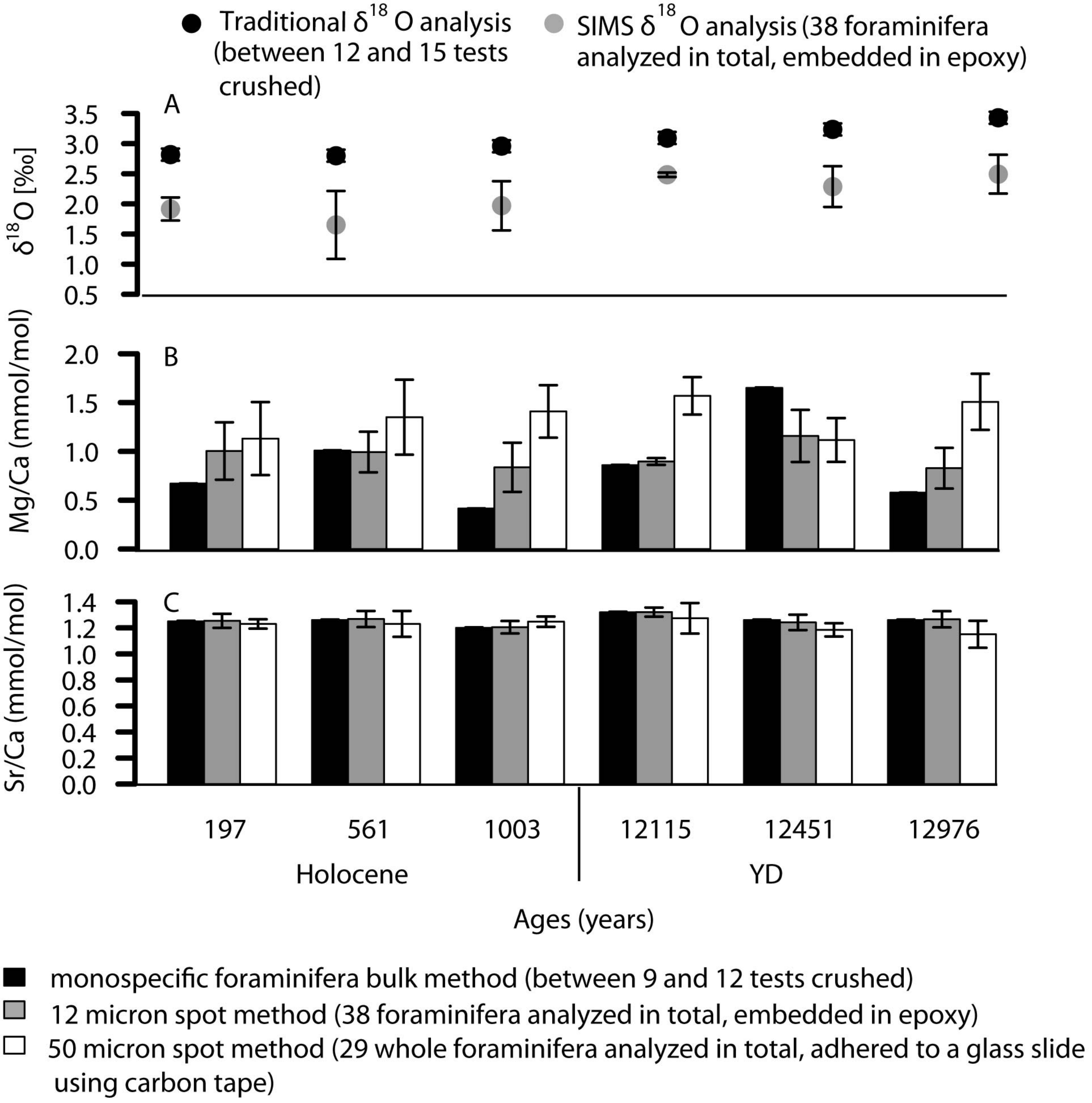

Traditional δ18 O analysis (between 12 and 15 tests crushed)
SIMS δ18 O analysis (38 foraminifera analyzed in total, embedded in epoxy)
A
δ18O [‰]
3.5
3.0
2.5
2.0
1.5
1.0
0.5
B
Mg/Ca (mmol/mol)
2.0
1.5
1.0
0.5
0.0
C
Sr/Ca (mmol/mol)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
197
561
1003
12115
12451
12976
Holocene
YD
Ages (years)
monospecific foraminifera bulk method (between 9 and 12 tests crushed)
12 micron spot method (38 foraminifera analyzed in total, embedded in epoxy)
50 micron spot method (29 whole foraminifera analyzed in total, adhered to a glass slide using carbon tape)

Figure 5