

1 SUPPLEMENTAL INFORMATION

2 Methods and Materials

3 *Estimating environmental parameters for modern brachiopod samples*

4 We used bathymetric maps to estimate depths for specimens lacking those data, assigning
5 depths from most likely brachiopod habitat for each locality (i.e. hard substrates in atlases). We
6 derived habitat temperature and salinity from the World Ocean Atlas 2013 (Locarnini et al.,
7 2013; Zweng et al., 2013) and carbonate chemistry parameters from the GLODAP v2 database
8 (National Center for Atmospheric Research Staff (Eds), 2014). We used CO2Calc to calculate
9 habitat pH from estimated carbonate chemistry data (Robbins et al., 2010). Due to some
10 specimens' uncertain sampling depths, use of atlases to infer environmental conditions, and
11 potential seasonal variability, we assign temperature estimates large uncertainties ($\pm 2^{\circ}\text{C}$). We
12 further recognize the considerable uncertainty inherent in using gridded datasets to infer the
13 parameters that are highly heterogeneous in natural environments, and we recommend future
14 work on modern brachiopods with well-constrained growth conditions, ideally also including
15 direct constraints on growth rates.

16

17 *Screening samples for alteration and contamination*

18 Reliable geochemical analysis of carbonate samples depends on avoiding contamination
19 (which typically can come from trace silicate or Fe-Mn oxide phases) and selecting well
20 preserved material that has not had its composition altered during diagenesis. Although
21 brachiopods are generally well-suited as geochemical archives (e.g., Veizer et al., 1999), careful
22 screening remains important for yielding reliable isotopic reconstructions (e.g., Buening, 2001).

We screened for silicate and oxide contamination based on element-to-calcium ratios, particularly focusing on Al to trace silicate leaching following established approaches. Published data from experiments using carbonate-rich samples suggest that $\delta^7\text{Li}$ values for leachates with $\text{Al/Ca} > 800 \text{ } \mu\text{mol/mol}$ might reflect silicate leaching (Pogge von Strandmann et al., 2013). More recent work on the effect of leaching procedures on $\delta^7\text{Li}$ values for samples with varying carbonate-to-silicate ratios suggests that Al/Ca limits vary based on phases present in sample matrices (Bastian et al., 2018). For this work, we expect that brachiopod shells should be carbonate-dominated and so adopt a conservative Al/Ca limit of $300 \text{ } \mu\text{mol/mol}$ to identify modern and fossilized brachiopod leachates with possible silicate contamination. We therefore exclude samples with Al/Ca ratios that exceed this cutoff (Pogge von Strandmann, 2008). This criterion led us to exclude one modern sample (with $\text{Al/Ca} = 1146.2 \text{ } \mu\text{mol/mol}$) and four fossil samples (Fig. S2). Modern specimen Mn/Ca and Fe/Ca values were also monitored to determine the influence of possible Fe-Mn oxide leaching; with the exception of the craniid specimen (M34), we found no evidence for elevated values of these ratios in our data (Table A1).

We combined multiple approaches to screen fossil specimens for diagenetic alteration prior to analysis (Fig. S2), informed by past work on other isotope systems in brachiopods. The diagenetic alteration of brachiopod geochemical signatures is recognized as being complex, and no one single method has proven successful in distinguishing alteration in all cases (Buening, 2001) — motivating our multi-pronged approach. We began by assessing microstructure preservation with scanning electron microscopy (SEM) and evaluating trace element incorporation based on cathodoluminescence (CL) microscopy (Figs. S3 and S4 show representative CL and SEM images, respectively).

We complemented the microscopy observations with geochemical evaluation. We used measured radiogenic Sr isotope ratios, recognizing that resetting of Sr composition in carbonates is likely to imply resetting of the Li system as well (Dellinger et al., 2020). We excluded fossil samples with more than ~10ppm difference between the measured $^{87}\text{Sr}/^{86}\text{Sr}$ value and that expected based on the seawater curve (McArthur et al., 2012), based on the age range known for each specimen from stratigraphy.

Diagenetic alteration was also evaluated based on Mn/Sr values, using $\text{Mn/Sr} > 1\text{mol/mol}$ as a threshold indicative of alteration (Veizer, 1983). While Mn/Sr ratios (as well as Mn/Ca and Sr/Ca ratios) have been used extensively to investigate carbonate diagenesis, it has been suggested that these ratios be used cautiously to screen macro-fossils such as brachiopods (Ullmann and Korte, 2015). In particular, diagenetic setting and fossil type should be considered when interpreting these ratios. Additionally, studies of modern brachiopod shells reveal variability in Mn/Ca and Sr/Ca ratios between different brachiopod taxa as well as within individual shells, which has been attributed to environmental conditions, shell growth rates, and/or varying growth mechanisms between shell layers (Ullmann et al. 2017; Rollion-Bard et al. 2019), potentially complicating the use of these element ratios for diagenetic screening. More work is needed to understand the relationship between environmental, physiological, and diagenetic factors that might influence Mn/Sr, Li/Ca, and Li isotope compositions of brachiopods.

An important consideration in using geochemical indices for diagenetic screening is that trace elements like Mn or Sr in a brachiopod shell may not necessarily reflect alteration of Li and its isotopes, especially if these elements may have different distributions within shells. Variable Li/Ca ratios have been observed in modern brachiopod primary layers and attributed to

complexity of the calcification mechanism, whereas secondary layers are more internally consistent within shells (Rollion-Bard et al., 2019). These observations lend some confidence to the use of secondary layers for Li analysis, although data on isotope distributions within brachiopod shells layers remains lacking — reflecting a worthwhile target for future work. If Li isotope compositions are heterogeneous within secondary layers, then preferential dissolution and loss of Li from isotopically distinct carbonate could influence measured bulk $\delta^7\text{Li}$ in ways that may not be picked up by trace element ratios. However, we would expect to see signs of such dissolution in SEM images, emphasizing the importance of combining multiple approaches to evaluating potential alteration.

Altogether, we identified alteration in 15 of the 41 leachates we analyzed (Fig. S2, and details in Table A2). Note that only two data points (UF1 and UF1 dup) were excluded based on the basis of Mn/Sr ratios, and these data are from duplicate measurements of the same specimen that showed signs of a high degree of alteration under SEM. Thus, while there is certainly room to improve understanding of the Li isotope preservation in brachiopods, we suggest that use of multiple screening approaches including detailed microscopy, Sr isotope stratigraphy, and trace element ratios provides a general framework that may be refined as more is learned in the future.

Brachiopod Biomineralization and Potential Effects on $\delta^7\text{Li}$

Given the lack of any clear relationship between $\delta^7\text{Li}$ compositions of brachiopods and their environmental conditions (Fig. 2), at least within the data from this study, another control on $\delta^7\text{Li}$ fractionation must be invoked. Effects associated with biomineralization are one possibility. In part because fossil specimens dominate research thus far on the phylum,

brachiopod biomineralization is incompletely understood. Proteomic studies suggest that, relative to other marine calcifiers, brachiopods precipitate their shells using a novel molecular mechanism. In the process, they might utilize an enzyme similar to that found in corals (α -carbonic anhydrase) to increase calcite precipitation rate (Jackson et al., 2015; Immel et al., 2015; Isowa et al., 2015). The secondary shell layer, most commonly used for reconstructions of paleoenvironmental conditions, is composed of calcite fibers that behave optically like single calcite crystals (Pérez-Huerta et al., 2018). Through many studies of brachiopod shell structure, Williams proposed that the different layers of the shell are produced by a single cell via a conveyor belt system (Williams, 1953, 1966, 1968a, 1968b; Williams and Rowell, 1965). In contrast, a recent study proposed that more than one cell participates in the precipitation of a single calcite fiber/crystal, suggesting that calcite fibers are formed via ion transport of calcium (along with trace/minor elements) and carbonate rather than forming elsewhere in the epithelium and being transported and secreted by cell vacuoles (Simonet Roda et al., 2019). Additionally, while Simonet Roda et al. (2019) did not find evidence of a metastable, amorphous calcium carbonate (ACC) precursor to brachiopod calcite, ACC has been observed in one study of a rhynchonelliform brachiopod (Griesshaber et al., 2009), while other researchers found that brachiopod shell fibers are composed of calcite nanospheres or granules. Within the order Terebratulida, triangular particles are present, which have not been observed in any other known calcifying organisms (Cusack et al., 2008; Pérez-Huerta et al., 2013).

Environmental conditions and/or trace element ratios may offer some insight into how biomineralization influences Li incorporation into brachiopod shells (Fig. S9). While there are no significant correlations between Li/Ca ratios and calculated habitat [DIC] or pH, Li/Ca ratios for all rhynchonelliform specimens in this study are positively correlated with Sr/Ca ratios ($r^2 = 0.4$).

However, Li/Ca ratios do not significantly correlate with Mg/Ca ratios, which is surprising given the similar ionic radii of Li and Mg. The relationship between Li/Ca and Sr/Ca may be due to the affinity for both Li^+ and Sr^{2+} to incorporate into calcite during rapid crystal growth. Theoretical studies suggest relationships between Li/Ca and Sr/Ca may emerge because imperfections at crystal surfaces are “entrapped” when calcite grows quickly, and Li and Sr share a high affinity for these traps; this is referred to as the growth entrapment model or GEM (Watson and Liang, 1995; Watson, 1996, 2004; DePaolo, 2011).

In contrast to Li/Ca, $\delta^7\text{Li}$ compositions are weakly negatively correlated with both their Sr/Ca ($r^2 = 0.18$) and Mg/Ca ($r^2 = 0.17$) ratios. While these are weak correlations, they suggest mechanisms controlling Sr and Mg incorporation into brachiopod shells might also influence Li isotope fractionation during shell formation. Although evidence for an ACC precursor in brachiopods is equivocal (see above), it could provide one explanation for the observed elemental behavior. Mg^{2+} and Sr^{2+} incorporation into calcite via ACC crystallization results in distortions of the crystal lattice. These distortions in turn affect the surrounding bonding environments. At high Mg^{2+} concentrations, Sr^{2+} inhabits a 9-fold coordination versus substituting for Ca^{2+} in smaller, more stable 6-fold coordination sites (Littlewood et al., 2017). If Sr^{2+} and Mg^{2+} were to distort the calcite crystal lattice in the presence of Li^+ , while Li^+ might normally inhabit a 6-fold coordination, some Li^+ ions might be trapped in 9-fold coordination. Given that Li is strongly bound in a tetrahedra of -OH groups in water (Olsher et al., 1991), when it coprecipitates with calcite, the bonding environment should greatly impact how the isotopes of Li fractionate. Given that the tetrahedral bonding environment is strongest versus octahedral or orthorhombic environments in calcite, the lighter isotope of Li has a greater affinity for the solid phase. This is supported by studies of Li isotopes in inorganically precipitated

136 calcite and aragonite – the $\delta^7\text{Li}$ of the solid phases is always lower than the fluid from which
137 they precipitated, with aragonite having a lower isotopic composition than calcite likely due to Li
138 inhabiting weaker bonding sites in aragonite than in calcite or water (Marriott et al., 2004b,
139 2004a; Gabitov et al., 2011). Thus, the bonding of Li in 9-fold coordination sites, driven by the
140 presence of distortions from Sr and Mg, could potentially explain why some brachiopod shells
141 have lighter $\delta^7\text{Li}$. Alternatively, faster diffusion of ^6Li versus ^7Li into calcification sites might
142 explain the tendency towards lighter compositions as Li is trapped if there is rapid crystal
143 growth. Verifying these proposed mechanisms, as well as evaluating how dependencies of shell
144 $\delta^7\text{Li}$ on growth rates or conditions, would clearly require further work.

REFERENCES FOR SUPPLEMENTAL TEXT AND FIGURES S1-S9

- Bastian, L., Vigier, N., Reynaud, S., Kerros, M.-E., Revel, M., and Bayon, G., 2018, Lithium Isotope Composition of Marine Biogenic Carbonates and Related Reference Materials: Geostandards and Geoanalytical Research, v. 42, p. 403–415, doi:10.1111/ggr.12218.
- Buening, 2001, Brachiopod Shells: Recorders of the Present and Keys to the Past. In: Brachiopods Ancient and Modern: A Tribute to G. Arthur Cooper, Paleontological Society Papers v.7, pp. 117–144.
- Cusack, M., Dauphin, Y., Chung, P., Pérez-Huerta, A., and Cuif, J.-P., 2008, Multiscale structure of calcite fibres of the shell of the brachiopod *Terebratulina retusa*: Journal of Structural Biology, v. 164, p. 96–100, doi:10.1016/j.jsb.2008.06.010.
- DePaolo, D.J., 2011, Surface kinetic model for isotopic and trace element fractionation during precipitation of calcite from aqueous solutions: Geochimica et Cosmochimica Acta, v. 75, p. 1039–1056.
- Gabitov, R.I., Schmitt, A.K., Rosner, M., McKeegan, K.D., Gaetani, G.A., Cohen, A.L., Watson, E.B., and Harrison, T.M., 2011, In situ $\delta^7\text{Li}$, Li/Ca, and Mg/Ca analyses of synthetic aragonites: Geochemistry, Geophysics, Geosystems, v. 12.
- Griesshaber, E., Kelm, K., Sehrbrock, A., Mader, W., Mutterlose, J., Brand, U., and Schmahl, W.W., 2009, Amorphous calcium carbonate in the shell material of the brachiopod *Megerlia truncata*: European Journal of Mineralogy, v. 21, p. 715–723, doi:10.1127/0935-1221/2009/0021-1950.
- Hall, J.M., Chan, L.-H., McDonough, W.F., and Turekian, K.K., 2005, Determination of the lithium isotopic composition of planktic foraminifera and its application as a paleo-seawater proxy: Marine Geology, v. 217, p. 255–265.
- Immel, F., Gaspard, D., Marie, A., Guichard, N., Cusack, M., and Marin, F., 2015, Shell proteome of rhynchonelliform brachiopods: Journal of Structural Biology, v. 190, p. 360–366, doi:10.1016/j.jsb.2015.04.001.
- Isowa, Y., Sarashina, I., Oshima, K., Kito, K., Hattori, M., and Endo, K., 2015, Proteome analysis of shell matrix proteins in the brachiopod *Laqueus rubellus*: Proteome Science, v. 13, doi:10.1186/s12953-015-0077-2.
- Jackson, D.J., Mann, K., Häussermann, V., Schilhabel, M.B., Lüter, C., Griesshaber, E., Schmahl, W., and Wörheide, G., 2015, The *Magellania venosa* biomineralizing proteome: a window into brachiopod shell evolution: Genome Biology and Evolution, v. 7, p. 1349–1362.
- Littlewood, J.L., Shaw, S., Peacock, C.L., Bots, P., Trivedi, D., and Burke, I.T., 2017, Mechanism of Enhanced Strontium Uptake into Calcite via an Amorphous Calcium Carbonate Crystallization Pathway: Crystal Growth & Design, v. 17, p. 1214–1223, doi:10.1021/acs.cgd.6b01599.

182 Locarnini, R.A. et al., 2013, World Ocean Atlas 2013, Volume 1: Temperature: NOAA National
183 Environmental Satellite, Data, and Information Service.

184 Marriott, C.S., Henderson, G.M., Belshaw, N.S., and Tudhope, A.W., 2004a, Temperature
185 dependence of $\delta^{7}\text{Li}$, $\delta^{44}\text{Ca}$ and Li/Ca during growth of calcium carbonate: Earth and
186 Planetary Science Letters, v. 222, p. 615–624.

187 Marriott, C.S., Henderson, G.M., Crompton, R., Staubwasser, M., and Shaw, S., 2004b, Effect of
188 mineralogy, salinity, and temperature on Li/Ca and Li isotope composition of calcium
189 carbonate: Chemical Geology, v. 212, p. 5–15.

190 National Center for Atmospheric Research Staff (Eds), 2014, GLODAP: GLObal Ocean Data
191 Analysis Project for Carbon | NCAR - Climate Data Guide:,
192 [https://climatedataguide.ucar.edu/climate-data/glodap-global-ocean-data-analysis-project-](https://climatedataguide.ucar.edu/climate-data/glodap-global-ocean-data-analysis-project-carbon)
193 [carbon](https://climatedataguide.ucar.edu/climate-data/glodap-global-ocean-data-analysis-project-carbon) (accessed December 2018)

194 Olsher, Uriel., Izatt, R.M., Bradshaw, J.S., and Dalley, N.Kent., 1991, Coordination chemistry of
195 lithium ion: a crystal and molecular structure review: Chemical Reviews, v. 91, p. 137–
196 164, doi:10.1021/cr00002a003.

197 Pérez-Huerta, A., Coronado, I., and Hegna, T.A., 2018, Understanding biomineralization in the
198 fossil record: Earth-Science Reviews, v. 179, p. 95–122,
199 doi:10.1016/j.earscirev.2018.02.015.

200 Pérez-Huerta, A., Dauphin, Y., and Cusack, M., 2013, Biogenic calcite granules—Are
201 brachiopods different? Micron, v. 44, p. 395–403, doi:10.1016/j.micron.2012.09.005.

202 Pogge von Strandmann, P.A., 2008, Precise magnesium isotope measurements in core top
203 planktic and benthic foraminifera: Geochemistry, Geophysics, Geosystems, v. 9.

204 Robbins, L.L., Hansen, M.E., Kleypas, J.A., and Meylan, S.C., 2010, CO2calc: A user-friendly
205 seawater carbon calculator for Windows, Mac OS X, and iOS (iPhone): US Geological
206 Survey.

207 Rollion-Bard, C., Garcia, S.M., Burckel, P., Angiolini, L., Jurikova, H., Tomašových, A., and
208 Henkel, D., 2019, Assessing the biomineralization processes in the shell layers of modern
209 brachiopods from oxygen isotopic composition and elemental ratios: Implications for their
210 use as paleoenvironmental proxies: Chemical Geology, v. 524, p. 49–66.

211 Simonet Roda, M. et al., 2019, Calcite fibre formation in modern brachiopod shells: Scientific
212 Reports, v. 9, doi:10.1038/s41598-018-36959-z.

213 Ullmann, C.V., Frei, R., Korte, C., and Lüter, C., 2017, Element/Ca, C and O isotope ratios in
214 modern brachiopods: Species-specific signals of biomineralization: Chemical Geology, v.
215 460, p. 15–24, doi:10.1016/j.chemgeo.2017.03.034.

216 Ullmann, C.V., and Korte, C., 2015, Diagenetic alteration in low-Mg calcite from macrofossils: a
217 review: Geological Quarterly, v. 59, p. 3–20, doi: 10.7306/gq. 1217.

- 218 Watson, E.B., 2004, A conceptual model for near-surface kinetic controls on the trace-element
219 and stable isotope composition of abiogenic calcite crystals 1 Associate editor: R.H.
220 Byrne: *Geochimica et Cosmochimica Acta*, v. 68, p. 1473–1488, doi:10.1016/j.gca.2003.10.003.
- 221 Watson, E.B., 1996, Surface enrichment and trace-element uptake during crystal growth:
222 *Geochimica et Cosmochimica Acta*, v. 60, p. 5013–5020.
- 223 Watson, E.B., and Liang, Y., 1995, A simple model for sector zoning in slowly grown crystals:
224 Implications for growth rate and lattice diffusion, with emphasis on accessory minerals in
225 crustal rocks: *American Mineralogist*, v. 80, p. 1179–1187.
- 226 Williams, A., 1968a, A history of skeletal secretion among articulate brachiopods: *Lethaia*, v. 1,
227 p. 268–287.
- 228 Williams, A., 1968b, Evolution of the shell structure of articulate brachiopods: *Special Papers in*
229 *Palaeontology*, v. 2, p. 1–55.
- 230 Williams, A., 1966, Growth and structure of the shell of living articulate brachiopods: *Nature*, v.
231 211, p. 1146.
- 232 Williams, A., 1953, North American and European Stropheodontids: their morphology and
233 systematics: *Geological Society of America*, v. 56.
- 234 Williams, A., and Rowell, A., 1965, *Treatise on invertebrate paleontology. H. Brachiopoda: Part*
235 *H*, v. 1.
- 236 Zweng, M.M. et al., 2013, *World Ocean Atlas 2013, Volume 2: Salinity*: NOAA National
237 *Environmental Satellite, Data, and Information Service*.

Supplemental Figure Captions

Figure S1: Bulk brachiopod $\delta^7\text{Li}$ compositions from this study and Dellinger et al. (2018) and primary layer brachiopod $\delta^7\text{Li}$ compositions by genus from this study (Dellinger et al., 2018). Symbols are the same as in Fig. 1, with the addition of new symbols for primary layer compositions measured in this study.

Figure S2: Circled samples are removed from the reconstruction of past seawater $\delta^7\text{Li}$ composition based on the specified screening criteria: A) $\text{Mn/Sr} > 1000 \text{ mmol/mol}$, B) differences between sample $^{87}\text{Sr}/^{86}\text{Sr}$ ratios over their stratigraphic age ranges relative to the marine $^{87}\text{Sr}/^{86}\text{Sr}$ LOWESS fit curve in ppm, as shown in Figure A1 (McArthur et al., 2012); C) $\text{Al/Ca ratios} > 300 \text{ } \mu\text{mol/mol}$; D) samples showing signs of poor preservation under SEM. Most specimens with poor preservation based on SEM images also show signs of diagenetic alteration based on criteria A-C, but one specimen, NZ4, was only excluded based on SEM images. See Figure S5 for the image of NZ4.

Figure S3: Cathodoluminescent images of fossilized brachiopods with varying degrees of alteration, revealed by greater luminescence. All images were made with a 2 second exposure time. More intense luminescence corresponds to more Mn and Fe in the calcite (Machel, 2000)

Figure S4: Scanning Electron Microscope images of fossilized brachiopods with varying degrees of preservation. Images in the first row are characteristic of well-preserved specimens, and images in the second row are representative of poorly preserved specimens. For specimens

from the Rhynchonellata class, suitable specimens have preservation of microstructures like fibrous secondary shell layer and prismatic tertiary layers (Garbelli et al., 2012, 2014). Separation of fibers or laminae potentially allows for fluids to flow through the shell, increasing the likelihood of diagenetic alteration, while amalgamation of secondary and/or tertiary layer fibers is indicative of alteration.

Figure S5: Fossil brachiopod Li isotope compositions over the past 70 Ma differentiated by taxonomic group. There is no systematic variability in Li isotope values when comparing different taxa with overlapping ages.

Figure S6: Relationship between modern brachiopod Li/Ca ratios and habitat temperature. Open symbols represent specimens without depth data. Lines show exponential fits through data as noted in the legend. In addition to the Li/Ca data from Dellinger et al. (2018) and this study, the plot includes data from Delaney et al. (1989) who reported Li/Ca ratios on selected brachiopod samples but not Li isotope compositions; therefore the equivalent samples do not appear on Fig. 2 of the main text. For the data from Delaney et al. (1989) and this study, specimens in the genus *Tichosina* are not included in the Li/Ca – Temperature calibrations. Note that, as reported in prior studies (both for foraminifera and brachiopods), there is an apparent temperature effect on Li/Ca ratios but not on Li isotope ratios.

Figure S7: $^{87}\text{Sr}/^{86}\text{Sr}$ ratios for fossilized brachiopods and the marine $^{87}\text{Sr}/^{86}\text{Sr}$ LOWESS Fit curve (McArthur et al., 2012). The lower figure includes all samples, while the upper figure

shows a subset of samples with $^{87}\text{Sr}/^{86}\text{Sr}$ between 0.7075 and 0.7095. Samples with $^{87}\text{Sr}/^{86}\text{Sr}$ ratios and stratigraphic ages that do not align with the marine $^{87}\text{Sr}/^{86}\text{Sr}$ record within analytical uncertainty are labeled and are excluded from the reconstruction of Cenozoic brachiopod $\delta^7\text{Li}$ in Figure 3.

Figure S8: A) Fossil brachiopod $\delta^7\text{Li}$ values over the past ~70 Ma. Blue rectangles are data from this study and gray circles are published foraminifer data (Misra and Froelich, 2012). Rectangle widths are ages from stratigraphy and $^{87}\text{Sr}/^{86}\text{Sr}$ values; heights reflect $\delta^7\text{Li}$ 1σ analytical uncertainty. B) Cenozoic seawater $\delta^7\text{Li}$ values from adding fractionation factors of 4‰ (this study) and 1‰ (Hall et al., 2005) to brachiopod and foraminifer $\delta^7\text{Li}$ values, respectively.

Figure S9: Relationships between Li/Ca ratios and A) calculated habitat pH, B) calculated habitat [DIC], C) Sr/Ca ratios, and D) Mg/Ca ratios for rhynchonelliform brachiopods. Data from Dellinger et al. (2018) are included when available (Dellinger et al., 2018). Symbols are the same as those previously described. There are no correlations between Li/Ca and pH, [DIC], or Mg/Ca, but there is a weak correlation between shell bulk shell Li/Ca and Sr/Ca ratios.

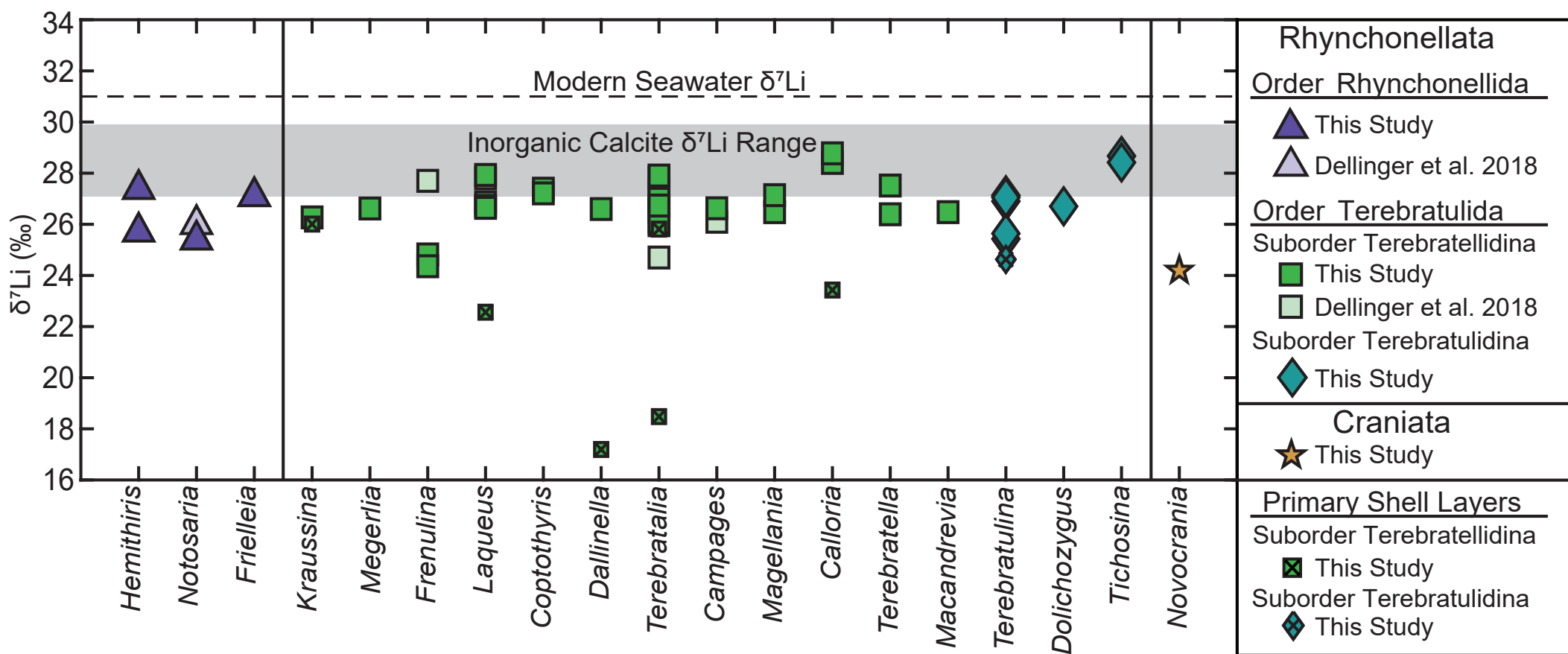


Fig. S1

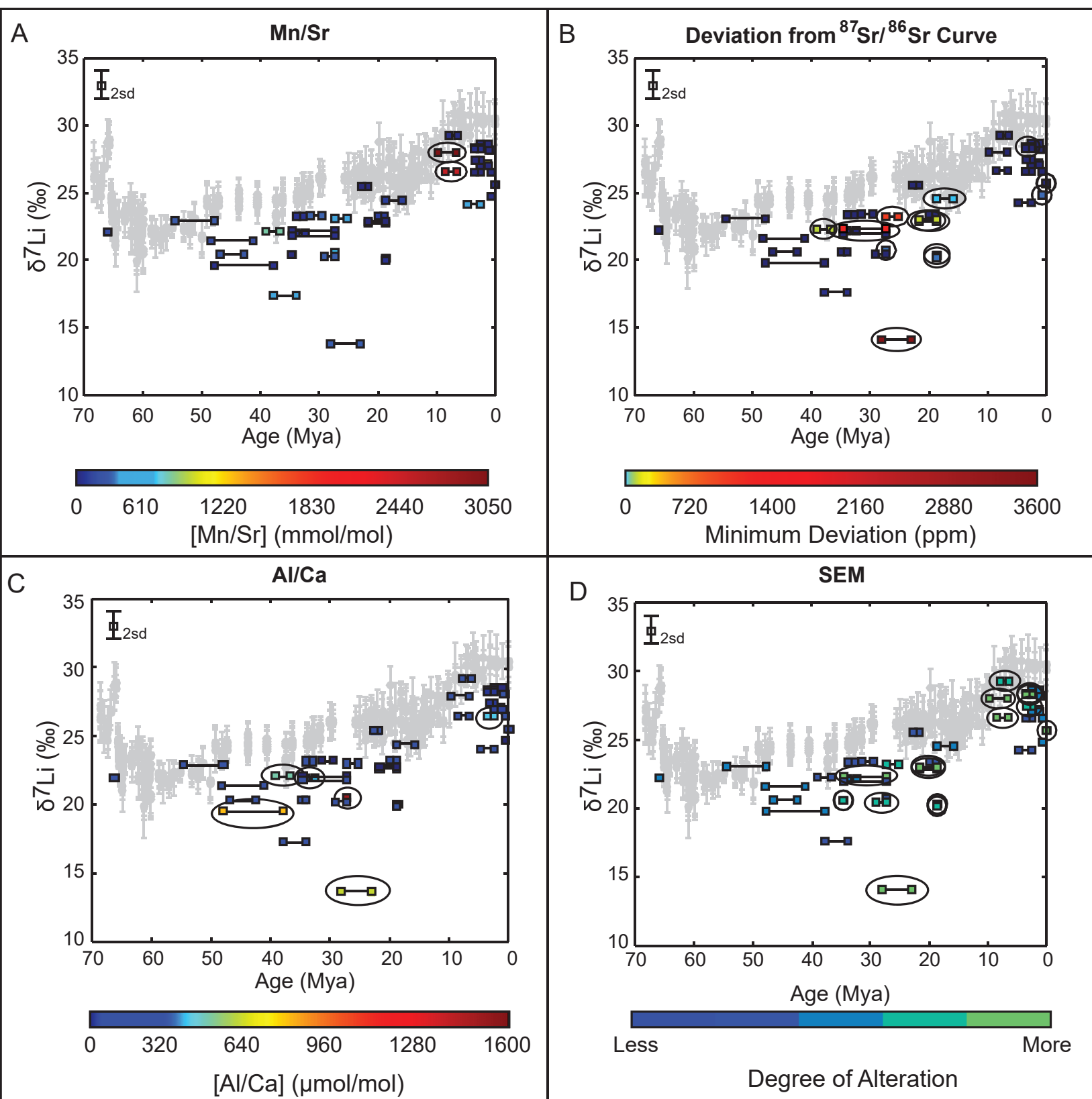


Fig. S2

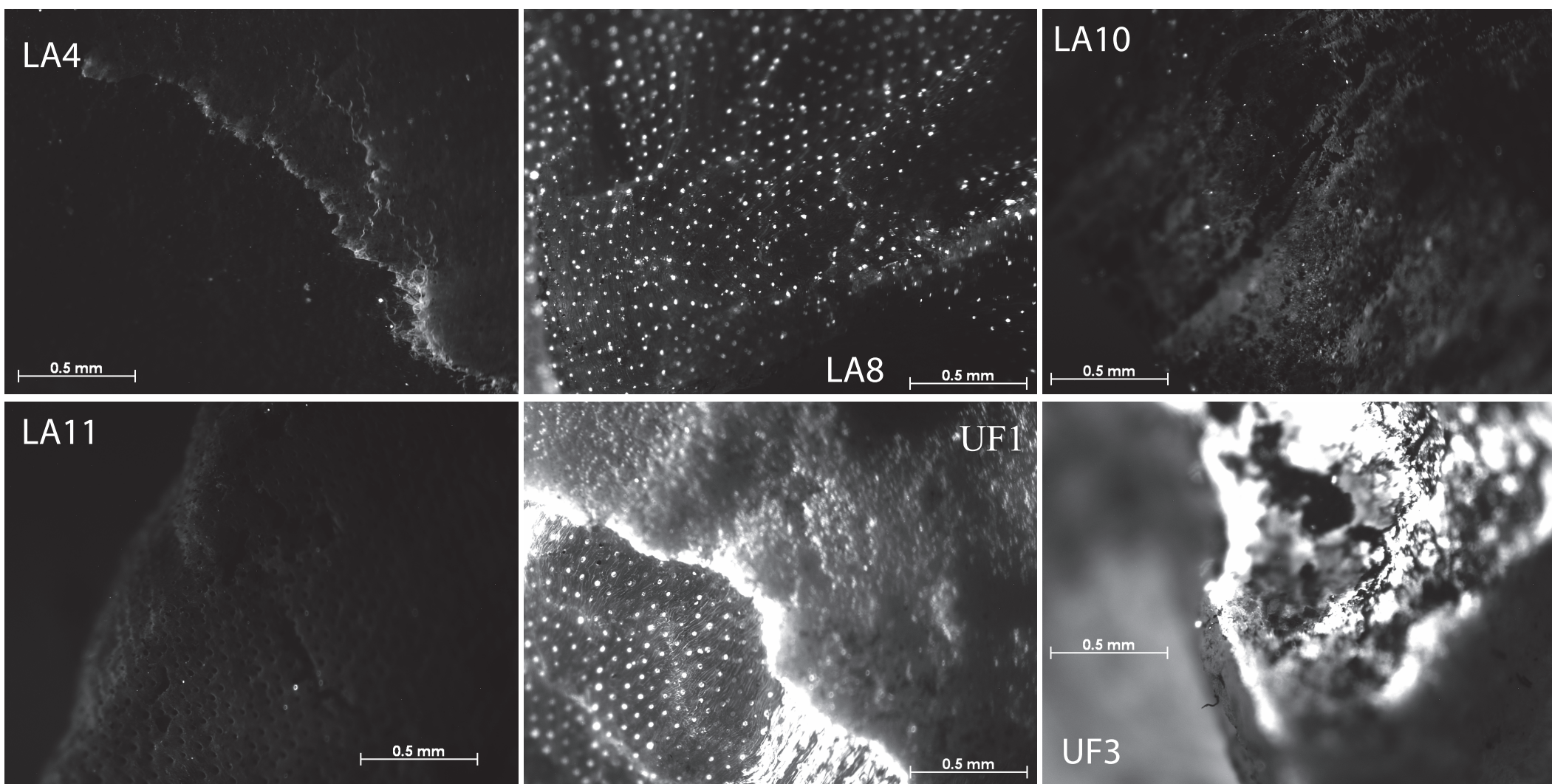
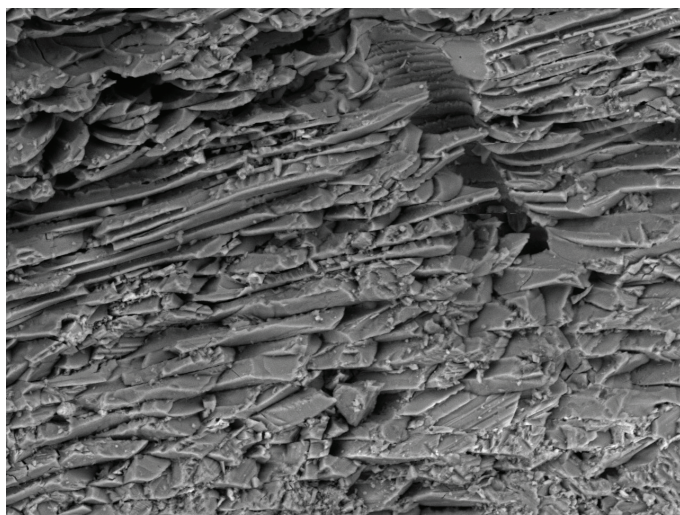
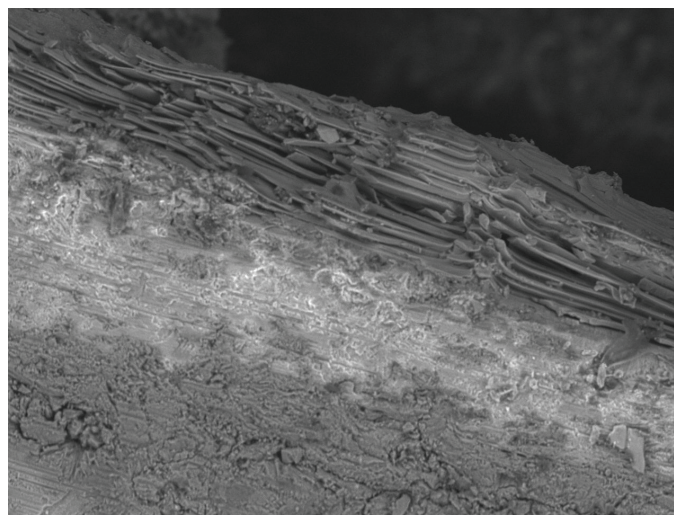


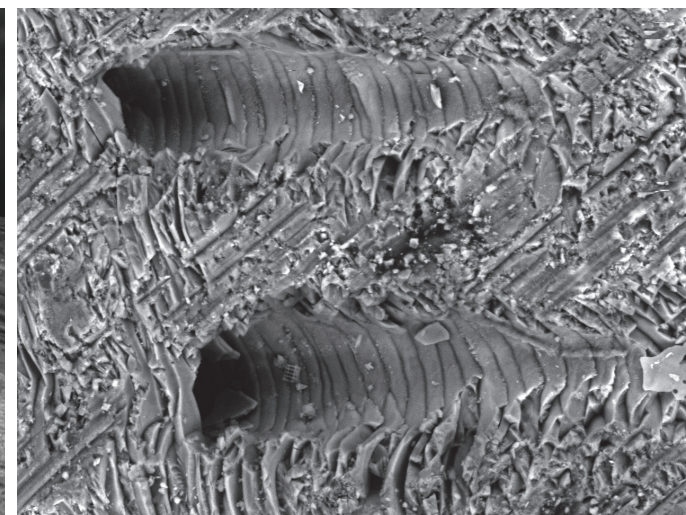
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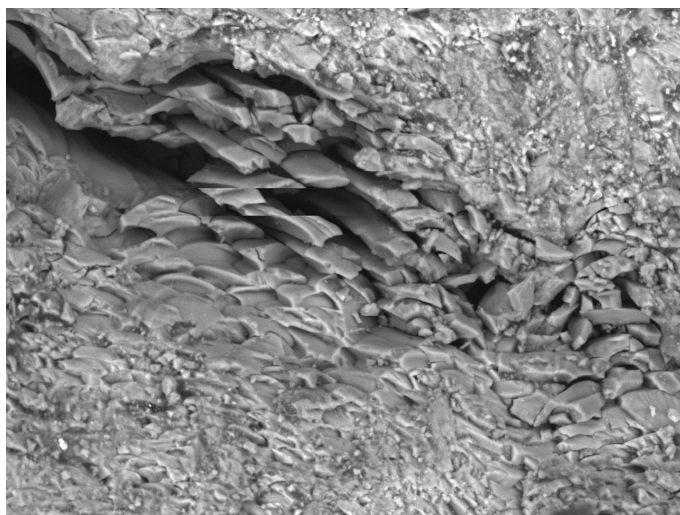
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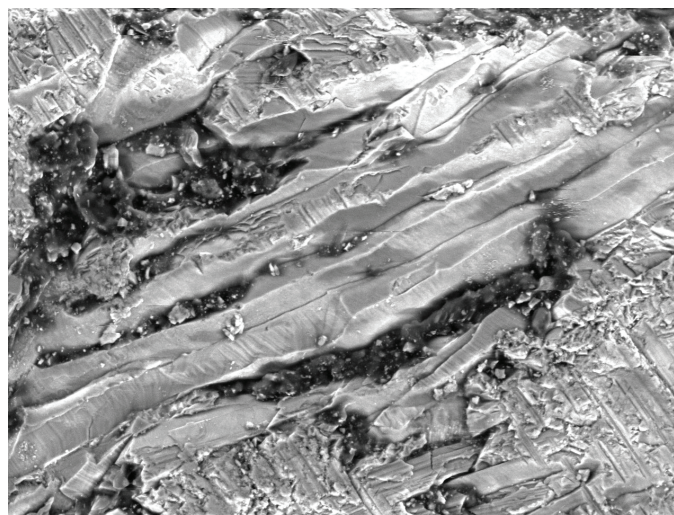
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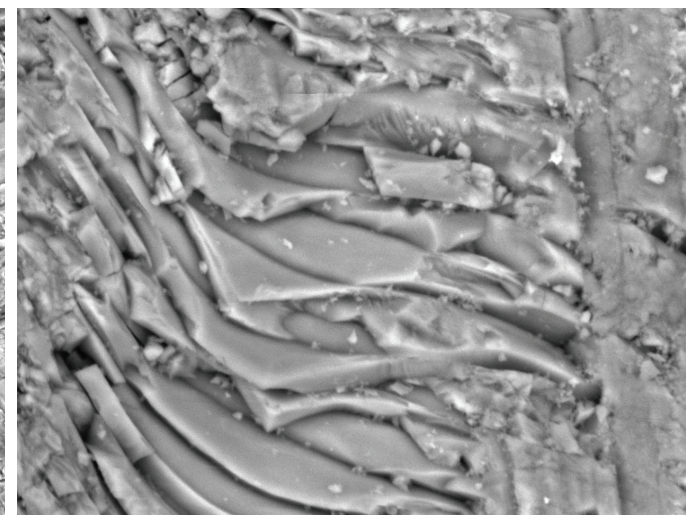
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UF1 2018/04/23 14:31 x1.5k 50 um



NZ4 2018/04/23 15:33 x1.2k 50 um



UF1 2018/04/23 14:28 x4.0k 20 um

Fig. S4

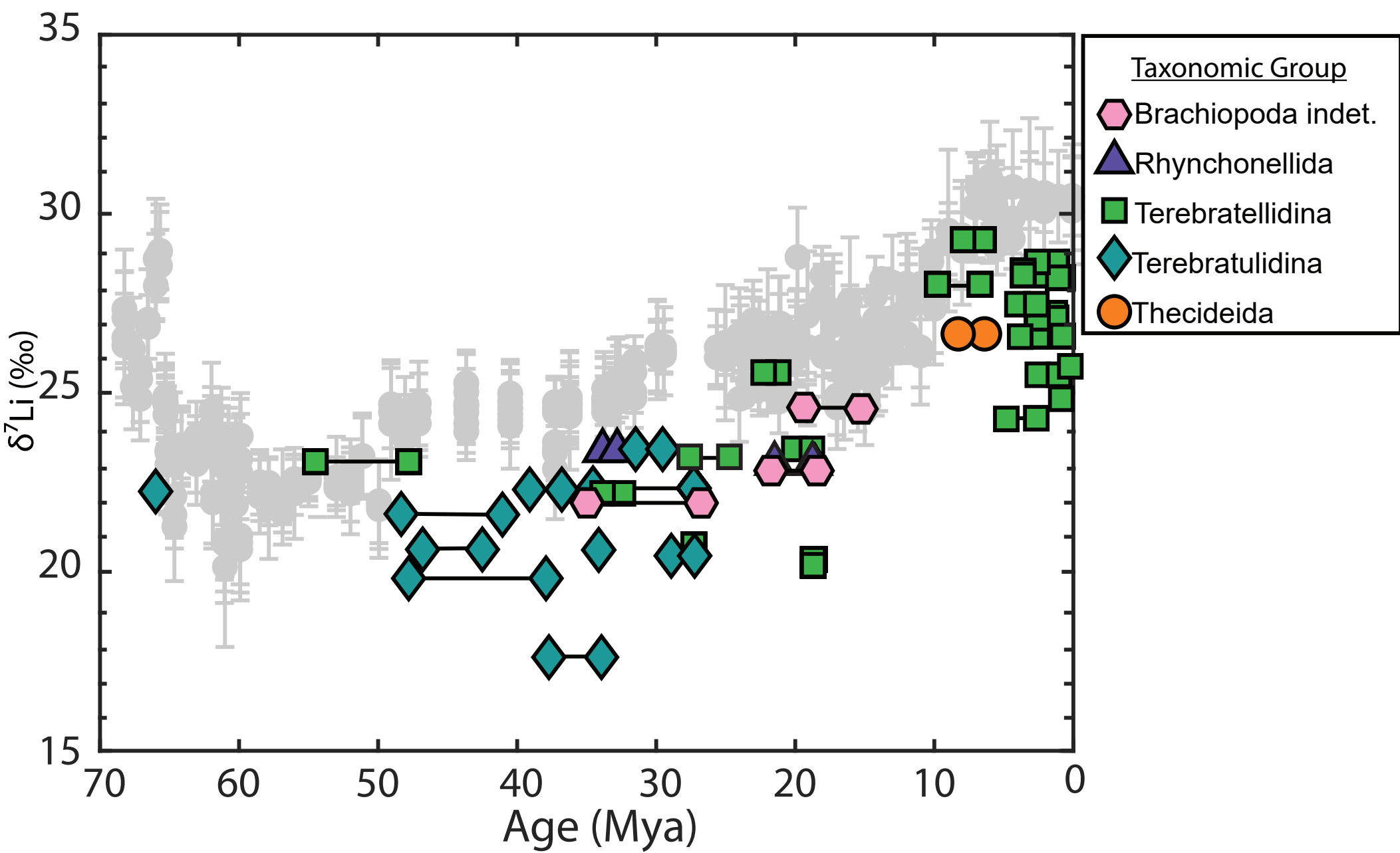


Fig. S5

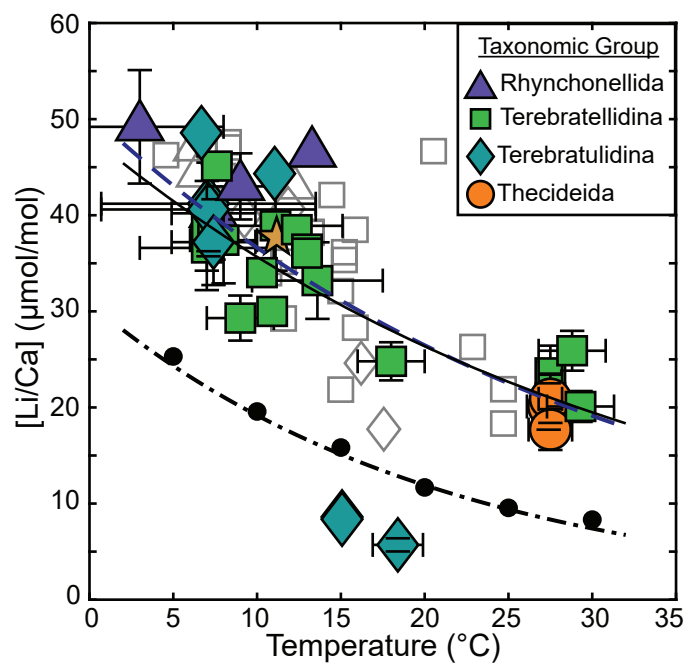


Fig. S6

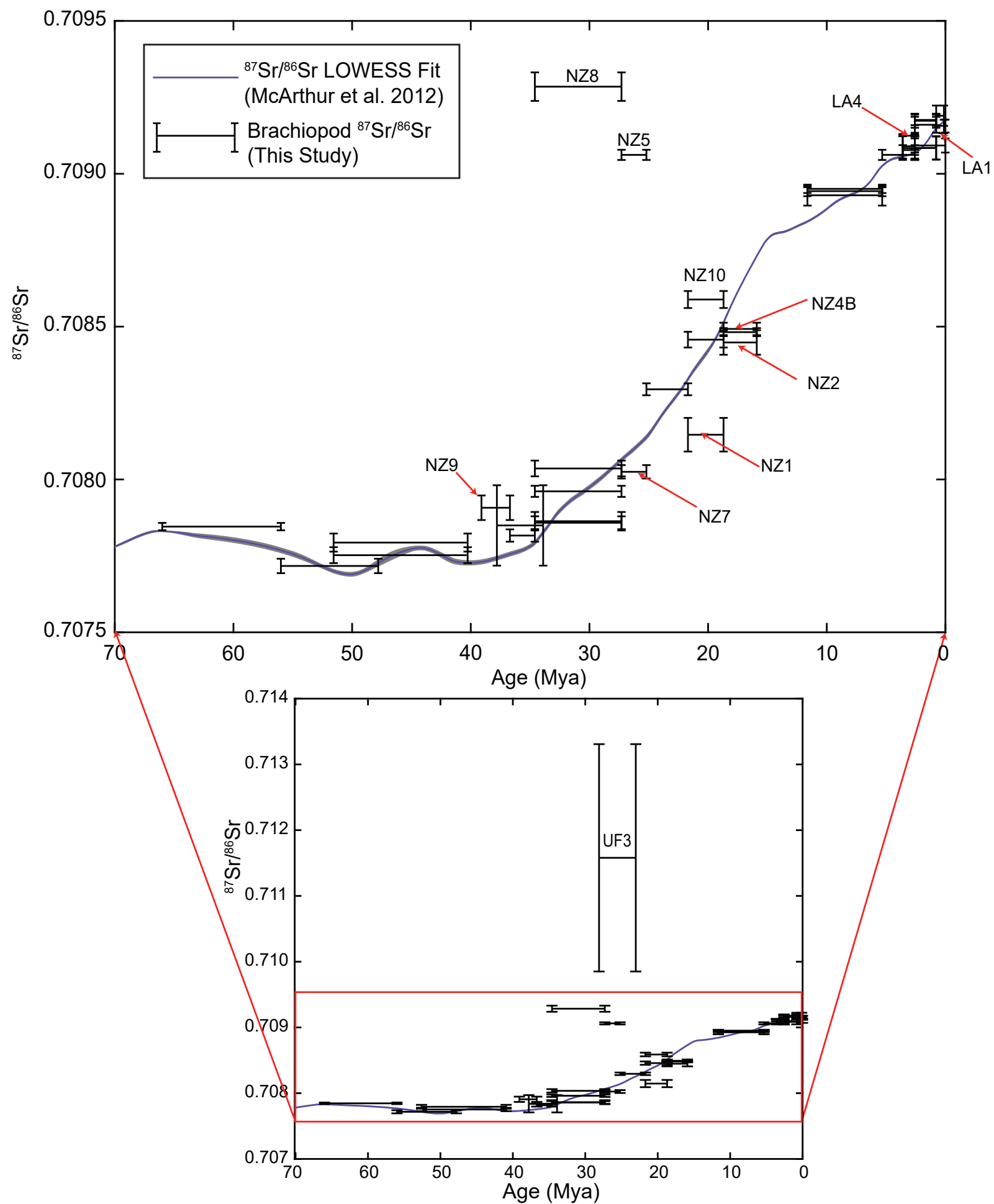


Fig. S7

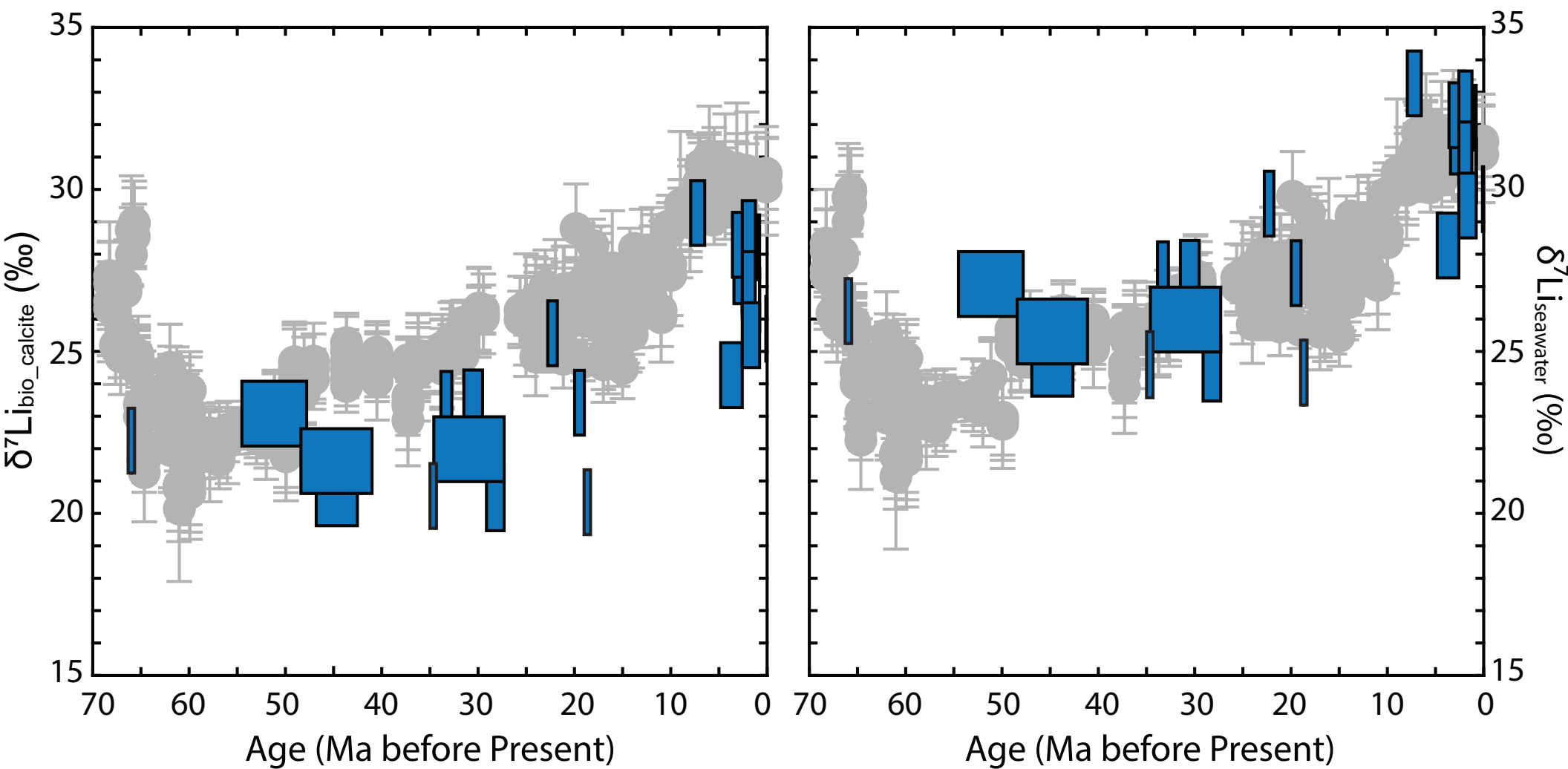


Fig. S8

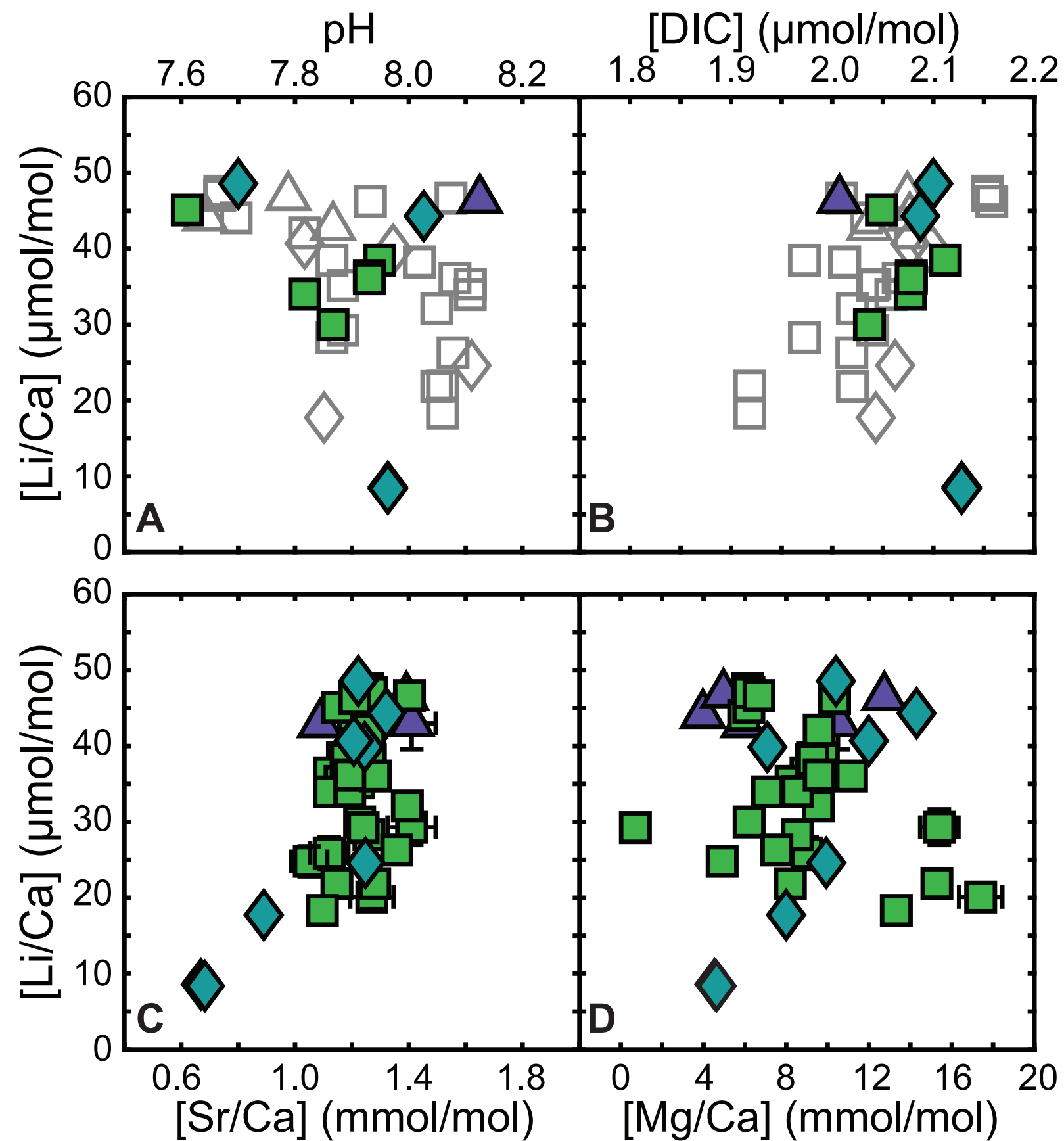


Fig. S9