# Supplemental Information 1: Searching for signs of early alteration and other "diagenetic" influences in speleothem SC-06-01

Our finding that the fluid inclusion isotopes do not lie on a single meteoric water line is consistent with the presence of two competing behaviours in precipitation isotopes of the region (Gat et al., 2003), but it could also arise from early alteration of the calcite after enclosure of the inclusions. We therefore consider it responsible to evaluate whether there is any evidence for such "diagenesis" within the sample, especially evidence of cements growing within speleothem cavities.

The speleothem comprises almost entirely of primary columnar calcite, with frequent zones of microcrystalline calcite oriented perpendicular to growth (Fig. S1). The columnar fabric is highly typical of speleothem growth in equilibrium with dripwater, whereas the micrite layers occur at hiatuses and are indicative of a degree of bio-influence (Frisia, 2015;Frisia et al., 2000;Dupraz et al., 2009). Micrite layers in SC-06-01 are an original fabric (Frisia, 2015). We find no evidence of either microsparite or mosaic fabrics within this specimen, and therefore no evidence of "diagenetic" alteration or transformation of an early carbonate phase.

Fluid inclusions themselves are unequally distributed, being far richer in milky layers typical of rapid growth phases than the rather glassy layers typical of slower growth (growth rate here in inferred from the distance between adjacent U-Th datings (Hoffmann et al., 2016). They are generally elongate, with their long axes oriented with the long axes of calcite columns. Larger inclusions universally show uneven margins, and no inclusion has been identified showing evidence of transformation towards a low aspect ratio, near-spherical form (Meckler et al., 2015). The larger inclusions generally have cuspate terminations, typical of inclusions formed during speleothem growth (Meckler et al., 2015). Smaller inclusions are also generally elongate, although some low aspect ratio inclusions can be found. Nevertheless, these resemble primary inclusions, with either cuspate or thorn-like closure in the growth direction.

Demény et al (2016) provide a vital framework for identification of alteration of fluid inclusions. Their work indicates that this process will be more common in cooler regions, making it relatively unlikely for an African specimen. Reconstructions of LGM winter-time (the likely season of maximum speleothem growth, and therefore fluid inclusion closure) sea surface temperatures for the Cyrenaican coast indicate a change from modern conditions <2°C (Hayes et al., 2005). This implies that cave temperature was likely no lower than ~18°C during MIS3.

Although Demény et al (2016) describe a process occurring in very young speleothems, they provide no upper age limit for Ostwald ripening to drive isotopic change in fluid inclusions. Looking for the signal of this process in SC-06-01, we find that the isotope measurements themselves do not systematically change with distance from speleothem top (age), but rather show a constant mean behaviour, with a slight bias to more negative values in Phase II rather than Phase I (Fig. 4). The

correspondence of the absolute magnitude of the measurements to modern rainfall isotopes for the region also requires that, for alteration *sensu* Demény (2016) to have taken place, these must perfectly compensate for some independent alteration of the system in the opposite direction. Moreover, although the broad distribution of the measurements in $\delta^{18}O_{fi}$ could arise from depletion during alteration (Demény et al., 2016), isotopically negative $\delta^{18}O_{fi}$ correspond to enriched $\delta^2H_{fi}$, causing a weak negative correlation between these values rather than a simple translation in oxygen isotopes. This is unlike the trend described by Demény et al (2016), but is consistent with the difference between Tunis-mode and Bet Dagan-mode rainfall today.

Overall, we therefore find no evidence in favour of alteration or "diagenetic" influence on the SC-06-01 fluid inclusion dataset. In absence of any such data, we feel on good grounds to interpret these data as palaeo-environmentally useful.

## References

Demény, A., Czuppon, G., Kern, Z., Leél-Őssy, S., Németh, A., Szabó, M., Tóth, M., Wu, C.-C., Shen, C.-C., and Molnár, M.: Recrystallization-induced oxygen isotope changes in inclusion-hosted water of speleothems–Paleoclimatological implications, Quaternary International, 415, 25-32, 2016.
Dupraz, C., Reid, R. P., Braissant, O., Decho, A. W., Norman, R. S., and Visscher, P. T.: Processes of carbonate precipitation in modern microbial mats, Earth-Science Reviews, 96, 141-162, http://dx.doi.org/10.1016/j.earscirev.2008.10.005, 2009.
Frisia, S., Borsato, A., Fairchild, I. J., and McDermott, F.: Calcite Fabrics, Growth Mechanisms, and Environments of Formation in Speleothems from the Italian Alps and Southwestern Ireland, Journal of Sedimentary Research, 70, 1183-1196, 10.1306/022900701183, 2000.
Frisia, S.: Microstratigraphic logging of calcite fabrics in speleothems as tool for palaeoclimate studies., International Journal of Speleology, 44, 1-16. , 2015.
Gat, J. R., Klein, B., Kushnir, Y., Roether, W., Wernli, H., Yam, R., and Shemesh, A.: Isotope composition of air moisture over the Mediterranean Sea: An index of the air-sea interaction pattern, Tellus, Series B: Chemical and Physical Meteorology, 55, 953-965, 10.1034/j.1600-0889.2003.00081.x, 2003.
Hayes, A., Kucera, M., Kallel, N., Sbaffi, L., and Rohling, E. J.: Glacial Mediterranean sea surface temperatures based on planktonic foraminiferal assemblages, Quaternary Science Reviews, 24, 999-1016, 2005.
Hoffmann, D. L., Rogerson, M., Spötl, C., Luetscher, M., Vance, D., Osborne, A. H., Fello, N. M., and Moseley, G. E.: Timing and causes of North African wet phases during MIS 3 and implications for Modern Human migration, Nature Scienfiic Reports, 6, 36367, 2016.
Meckler, A. N., Affolter, S., Dublyansky, Y. V., Krüger, Y., Vogel, N., Bernasconi, S. M., Frenz, M., Kipfer, R., Leuenberger, M., and Spötl, C.: Glacial–interglacial temperature change in the tropical West Pacific: a comparison of stalagmite-based paleo-thermometers, Quaternary Science Reviews, 127, 90-116, 2015.
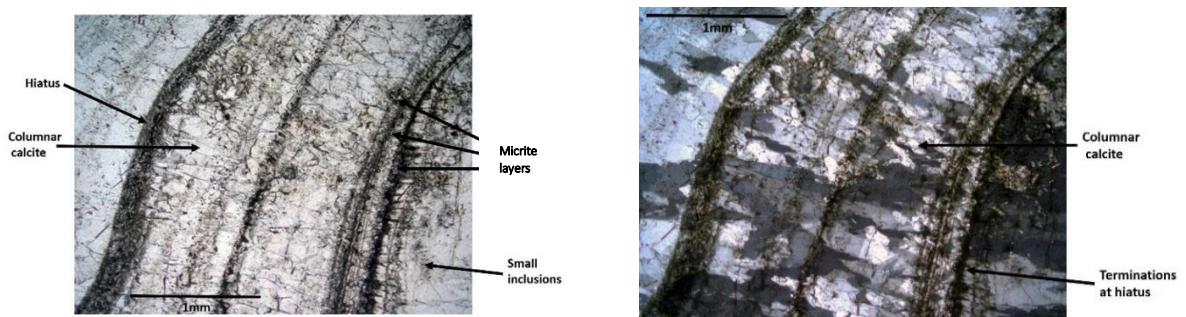
Figure S1. Typical fabrics of SC-06-01; Left PPL, right XPL.
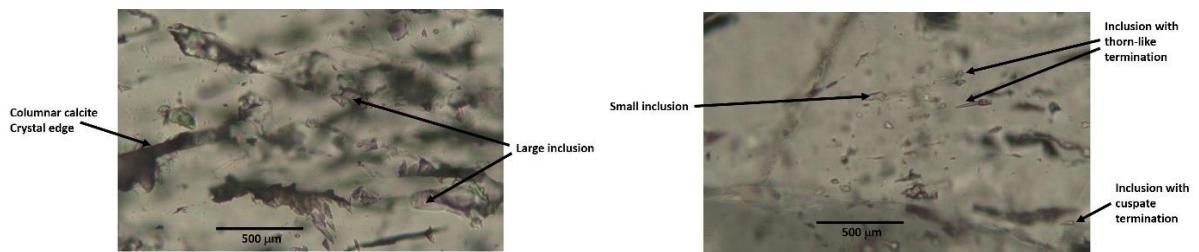
Figure S2. Typical fluid inclusions from SC-06-01; left larger inter-crystalline inclusions, right smaller intra-crystalline inclusions.