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Speleothem rubble as a new low-impact tool for cave-based palaeoclimate studies

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As speleothems become increasingly valued for their scientific importance and aesthetics, the pressure on cave environments grows. Several recent scientific studies have stressed the necessity of low-impact sampling strategies such as pre-screening, mini-coring and re-installation of samples after use to reduce unnecessary damage. The great abundance of speleothem 'rubble' in caves, however, suggests another highly-promising tool for low-impact scientific study. Here this concept is applied to the World Heritage Naracoorte site in South Australia under the assumption that the age frequency distribution of randomly sampled rubble from a family of caves will reflect periods of enhanced and reduced effective precipitation. 112 individual samples (stalagmites, stalactites and flowstones) were collected from thirteen caves in the Naracoorte region, and dated with U-Th techniques. We observe no correlation between sample size (diameter of stalagmites and stalactites) and age, suggesting that there is little if any bias related to rubble form/preservation. To produce the frequency distribution, a Kernel Density Estimator (KDE) was used rather than the typically employed Probability Density Function (PDF), because the latter rewards ages with small uncertainties producing spiky peaks. In addition, absolute age-uncertainties vary with age for the U-Th method which also introduces bias into a PDF. The effect of the uncertainty and the KDE's smoothing parameter (bandwidth) were examined by a Monte Carlo simulation of the KDE, a simple model that can easily be applied to other studies. The simulation shows that peaks are convincingly stable up to 300-350 ka. After 350 ka, the intensity and location of the peaks become more difficult to interpret and should be treated with care. The exponential relationship in the natural decay of speleothem material (i.e. a decrease in the number of old stalagmites) reported in recent work was not observed in this study. We suggest that under-sampling and non-random sampling may cause spurious trends in speleothem age frequency distributions, and that their influence should be thoroughly studied for each family of speleothems. The rubble sampling method offers great promise for palaeoprecipitation studies but can also provide valuable information on the timescales of karst processes and, when combined with other proxy methods (e.g. speleothem palynology), offers a novel, low impact method of palaeo-environmental reconstruction.