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U-series and radiocarbon cross dating of speleothems from Nerja Cave (Spain): Evidence of open system behavior. Implication for the Spanish rock art chronology

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ABSTRACT

Two stalagmites from Nerja cave (Andalusia, Spain) were studied. The cave is well known because of its long human occupation from the Upper Palaeolithic to the Chalcolithic and its abundant parietal prehistoric Art. The aims of this study were twofold: i) to compare uranium/thorium ($^{230}Th/^{234}U$) and Carbon-14 (^{14}C) ages obtained all along the growth axis of the stalagmites in order to understand the consequences of diagenetic processes on the validity of radiometric ages; ii) as one of the stalagmites contains black layers, attributed to combustion soot, to establish when these intense hearths were used and by which culture.

$^{230}Th/^{234}U$ and ^{14}C ages were coupled with mineralogical studies using FTIR (Fourier-transform infrared *spectroscopy)* and thin section observations. The first stalagmite (GN16-9b) displays $^{230}Th/^{234}U$ ages in stratigraphic order, and compatible with ^{14}C ages corrected for a few percent of dead carbon. Homogeneous composition of aragonitic crystals characterized by their needle-like texture is observed throughout this speleothem. For the second stalagmite (GN16-7), in contrast, $^{230}Th/^{234}U$ ages display large significant inversions and discordant results on the upper part and at the base of the stalagmite, suggesting a possible open system behavior for this chronometer. Interestingly, ^{14}C ages are in stratigraphic order all along the stalagmite and are compatible with $^{230}Th/^{234}U$ ages only in its central part. Mineralogical studies display evidence of aragonite to calcite transformation at the top and a complex mineralogical assemblage with interlayered silicates (possibly clays) and calcitic mineralogy for the base of GN16-7. In these parts, discordant $^{230}Th/^{234}U$ ages were measured. In the middle part of the stalagmite, however, where the fibrous aragonite is well preserved, the ^{14}C and $^{230}Th/^{234}U$ ages agree. Our data suggest that in the case of aragonite to calcite transformation as shown here, $^{230}Th/^{234}U$ ages are biased, but ^{14}C ages seem to remain accurate, as already observed in aragonitic marine bio minerals. ^{14}C ages obtained are used for the chronology of the soot layer, determined here between 7900 and 5500 years Cal BP, coherent with previous analysis of charcoals in the same sector of the cave. This study highlights the importance of working with at least two chronometers when stratigraphic age verification is not possible, as is the case of some parietal $CaCO_3$ thin layers used for rock art dating. Recent $^{230}Th/^{234}U$ ages published for carbonate deposits on Spanish parietal Art are discussed in light of this demonstration.

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