U-Th dating of ostrich eggshell: Understanding the relationship between eggshell microstructure and diffusion and implications for sample preparation

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Abstract: Dating the Middle Stone Age (~250-30 ka) is of great importance to studies of human evolution because this time period witnessed the origin of modern Homo sapiens in Africa. Its migration out of the continent (see map at right) and across the rest of the world, advances in stone tool manufacture, and changes in hunting strategies. Techniques such as U-Th dating of ostrich eggshell (OES) has often been used to establish the age of archaeological sites. Uranium (U) diffuses into the OES crystal structure after burial, and measurement of U and Th decay product, along with an estimation of U diffusion rates (Sharp et al., 2012) into the OES enables a determination of the time of burial. OES age determinations can be complicated by the incorporation of detrital Th into soil from into the OES. Sharp et al. (2011) showed that the external OES layers contain high detrital Th, and Lawey et al. (2015) demonstrated that the pores on the internal palisade layer also contain high detrital Th. Pores provide a critical avenue between the external and internal surfaces of the OES for Th to infiltrate the eggshell. We completed high-resolution CT scans of OES to map the number, 3D pattern, and volume of the pores. Rather than a single pore, the structure consists of numerous very small "satellite" pores oriented circumferentially around a large central pore. Total pore volume can be significant. In order to minimize the effect of detrital Th, we recommend that sample preparation combine the removal of the two outside layers of the eggshell with drilling out the area around each pore. Minimizing detrital Th diminishes the impact of the correction calculation, which is critical for precise age determinations.

Effective Age Range of Dating Methods

Commonly-used radiocarbon dating can only be applied to the youngest end of this time interval. More human groups collected ostrich eggs for food, and used the empty shells as containers. Therefore, many sites contain ostrich eggshells. U-Th dating of ostrich eggshell (OES) may be useful to establish the age of archaeological sites. Uranium from soil diffuses into the OES crystal structure after burial and decays to Th. Measurement of U and Th decay product enables determination of the time since burial. Two issues limit precise age determination: 1) the lack of constraints of the rate and timing of U diffusion into the OES after burial; and 2) incorporation of Th into the OES from infiltration of Th-rich soil particles into pores and cracks of the OES.

U-Th dating

In an ideal situation, U would diffuse into the OES quickly after burial and then diffusion would stop so that the OES structure would remain as a closed box. The U would decay to Th inside the OES, and subsequent measurement of U and Th would reflect the timing of burial of the OES. If diffusion was slow and occurred continuously while the OES was buried, then the calcula U-Th age would be younger than the actual burial age. Ongoing work attempts to understand diffusion (Sharp et al., 2014, 2015) and see discussion of our future work at left).

Soil Th:

In an ideal situation, all of the Th in an ancient OES would come from the decay of U. However much of the Th in OES comes from soil particles that also fill the round pores of the OES (Lawey et al., 2014) and the cracks in the exterior crystal and inner crystal layers (Sharp et al., 2014). The surplus of Th from the decay of U is 1.400. The soil Th is mostly 1.400, but includes a little 1.400. To determine the amount of 1.400 Th from decay of U, we must subtract the 1.400 Th from the measured Th.

Results

Ongoing Work

We are testing rates of U diffusion and Th-rich particle infiltration. Six fragments of the modern OES were placed in teflon jars, 3 with soil (Th) and 3 with soilless powder (local SM-1), and distilled water and heated to 60°C, the average soil temperature at SM-1. After 6 months, 1 year, and 2 years, we will measure distribution of U and Th across OES using laser ablation ICP. We hope visible changes in OES with high resolution microscopy, and analyse U and Th concentrations using TIMS.

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References

