Ore origin of Middle-Bronze Age copper artefacts from Sidon

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Over one hundred burials dating from the Middle Bronze Age (2000-1550BC) have been excavated in Sidon since 1998 under the direction of The British Museum and the Department of Antiquities [1]. These excavations led to the discovery of copper (Cu) artefacts (named "bronzes" according to the regional archaeological terminology) that could provide unique indication on the origin of metal used to manufacture them, and therefore help elucidate trade relations between the Levantine coast and the rest of the Mediterranean. These artefacts included weapons (daggers, knife, arrow head, spear head), jewels (torque, belt) and some miscellaneous (pin, fish hook). Our goal was to determine the geographic origin of the mines from which Cu were extracted by means of stable lead (Pb) isotopes that are efficient tracers of Cu, Pb and Ag ore sources [2] [3].

Lead isotope ratios from twenty-eight Bronzes were compared to well-known antique Cu and Pb ore body isotope signatures from Crete, Greece, Turkey, Oman, Sardinia, Spain, Italy, Cyprus, Egypt, Southern Levant, Iran-Iraq and Syria. Both Cu and Pb ore imprints from the same geographic area generally overlap except in the Taurus region and Egypt. The three most common possible geological origins for these bronzes were located in Cyprus, Crete, and, more unexpectedly, in the Cu rich Oman Gulf region. Only one artifact could be related to the abundant Southern Levant Cu mines in spite of its geographic proximity to Sidon and none to Egypt or any other location in the Western Mediterranean basin. Silver (Ag) artifacts from two burials were attributed to Turkish sources. No clear pattern between provenances, as determined by Pb isotopes, burial's chronologies and objects could be established. Trace element analyses were used to resolve source uncertainties associated with mixed/recycled ores and corrosion.

This archeometric approach confirmed archaeological findings about possible networks bewteen the Aegean, Cyprus, Turkey and Sidon more than three thousands years ago. The Gulf of Oman is less likely reliable as a trade partner, but could not be denied on the basis of Pb analyses only.

[1] Doumet-Serhal (2007) in *The Bronze Age in Lebanon*, 11-44, eds. M. Bietak and E. Czerny. [2] Gale and Stos-Gale (1982) *Science* **216**, 4541, 11-19. [3] Gale (2001) *European Journal of Archaeology* **4**, 1, 113-130.

Earthworm secreted calcium carbonate – a new palaeothermometer?

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Oxygen and carbon isotope ratios of calcium carbonate skeletons, produced by a range of aquatic and terrestrial organisms, have often been found to be useful proxies for environmental variability [1]. Although they do not form skeletons, many earthworm species are true biomineralisers, secreting granules of intricately zoned calcite [2]. These granules are frequently found in archaeological finds and buried soils. We are currently investigating the utility of stable isotope compositions of earthworm secreted calcite granules for reconstructing past environments.

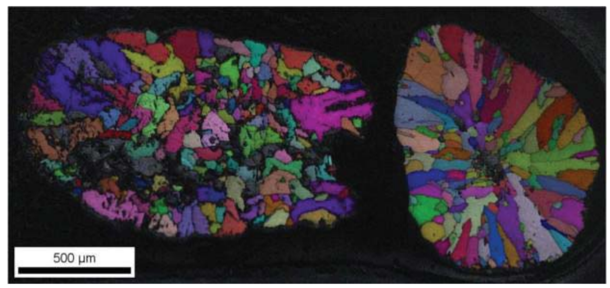

Figure 1: Electron Backscatter Diffraction (EBSD) orientation contrast maps of two Pleistocene earthworm granules highlighting their polycrystalline microstructure. Image by Martin Lee, School of Geographical and Earth Sciences, University of Glasgow.

Experiments were designed in which individual earthworms (*Lumbricus terrestris*) were kept in bags of soil for up to four months. Two different types of soil (C3 and C4 vegetation) were used, which were air-dried and then moistened with three isotopically different types of mineral water. The experiment was performed at three different temperatures. $\delta^{13}C$ and $\delta^{18}O$ values were measured for the soil organic matter, soil pore water, food (manure), soil air, earthworm tissues and $CaCO_3$ granules. Preliminary results show that the $\delta^{18}O$ values of the granules accurately reflect those of the pore water, in a similar way as for inorganically precipitated calcite. $\delta^{13}C$ values appear to reflect those of food offered to the earthworms.

In combination with U/Th dating, the stable isotope composition of earthworm secreted calcite granules can likely help in the reconstruction of past temperatures, vegetation and soil organic matter composition. As such it provides a much needed new terrestrial proxy for the reconstruction of past environments in archaeological and geological contexts.

[1] Versteegh et al. (2010) *Geochemistry, Geophysics, Geosystems* **11**, 16. [2] Lee et al. (2008) *Geology* **36**, 943-946.