# Below the threshold: the importance of shell middens' sedimentary context to recognize Mesolithic shellfish cooking

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**Abstract**

The high reliance on marine resources and associated harvest of mollusc is common in the European Mesolithic. While it is clear that shells are associated with subsistence strategies, it remains unclear if, and how, these dietary items were processed. An important aspect is to know if molluscs were commonly cooked or eaten raw. If we look at ethnographic studies, there are several examples of shellfish processing and roasting practices in the absence of ceramic containers, and these often involved the displacement of the original combustion residues to retrieve the opened shells. Few studies have, however, focused on establishing shell roasting signatures in archaeological datasets. One way to tackle the question of fire use to process shellfish is to investigate mineralogical changes of archaeological shells. Mineralogical transformations – namely the loss of organic components and the CaCO3 polymorphic conversion from biogenic aragonite to calcite phases – occurs progressively with increased temperatures from _˜250°C until 450°C. However, it is hard to reconcile exposure to temperatures above 250°C with cooking since this would most probably entail the burning of the eatable meat.
To distinguish between cooking and burning, here we investigate mineralogical temperature related alterations of biogenic aragonite alongside studies of site formation processes. We combined micromorphology analyses – providing microstratigraphic and site formation data – with contextualized micro Fourier Transform Infrared spectroscopy (microFTIR) data taken directly on shells in thin section. We focused on both modern and archaeological shells of *Cerastoderma edule* and *Scrobicularia plana*, as these are commonly exploited species in the Portuguese Mesolithic shell middens and are both originally aragonitic.

Our results confirmed previous data on modern specimens exposed to different controlled temperatures, namely that: (1) the CaCO3 conversion is gradual, with both aragonite and calcite phases persisting on shells from both species at the temperature interval of 250°C-450°C; (2) a complete conversion to calcite occurs at _˜450°C for both species, but starts

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at slightly different temperatures for each one, _˜250°C for *C. edule* and _˜350°C for *S. plana*. The microFTIR mapping allowed to obtain several FTIR spectra within a shell in thin section, and showed two further aspects: (a) that spectra of aragonite, calcite, and both polymorphs mixed co-exist in a same shell in the temperature conversion interval, revealing that the conversion is heterogenous; (b) it showed a markedly abrupt conversion point at _˜400°C for *S. plana*, while *C. edule* shows a progressive conversion throughout the 250°C-450°C interval.

Our study on archaeological shells in micromorphological thin sections measured the mineralogical conversion of shells in their microstratigraphic context using intact sediment samples from two Mesolithic shell middens in Portugal: Cabeço da Amoreira (Muge) and Poças de São Bento (Sado). Our results revealed several key aspects for recognising burning and possible cooking of shellfish. First, episodes of in-situ fireplaces that were invisible macroscopically could be identified. These invisible fires were revealed by the distribution of the microFTIR spectra with a gradual transition from calcite spectra in the above shells, with spectra mixing both polymorphs in a transitional zone, and only aragonite spectra in the lower shells. This evidence suggests that the conversion occurred in-situ, produced by a fire placed on top of the shell heap. Second, shellfish cooking residues were inferred from the association of charcoals in secondary position and associated shells yielding aragonite spectra, thus were not burnt above _˜350°C. This relates to discard of embers and shells from a nearby hearth without burning the shellfish, and this association is interpreted as debris from shellfish roasting fires.
This study reveals often invisible aspects of Mesolithic shell midden development and formation dynamics. The polymorphic conversion of shells within their microstratigraphic context, allowed for the recognition of shells burnt in-situ by a (macroscopic) invisible fire, even if charcoals and ashes are absent. Cooking residues were identified by charcoals in secondary position with shells exposed to temperatures high enough to open the bivalve but not to burn it. This evidence highlights that it is not expectable to recognize cooking by analysing individual shells' mineralogical properties, but rather by considering them within their original stratigraphic context.

**Keywords:** Shell middens, Cooking, Microstratigraphy, FTIR