Extensive reworking of Pliocene sapropels by low-oxygen adapted benthic meiofauna

Stefan Löhr[1], Martin Kennedy[1]
[1]Department of Earth and Planetary Sciences, Macquarie University, Australia, stefan.loehr@mq.edu.au

The dynamic interaction between marine sediments and burrowing fauna represents one of the key biogeochemical processes on Earth. Benthic animals facilitate sediment irrigation and oxygen ingress through burrowing and accelerate organic matter (OM) degradation through ingestion, physical comminution and enzymatic breakdown. Since their proliferation in the Cambrian, animal burrowers have left an indelible signature on the sedimentary record in almost all marine environments, with the seeming exception being low oxygen environments. In modern environments, however, sub-mm benthic meiofaunal animals are adapted to low oxygen, even sulfidic conditions. Though less well known than the larger benthic fauna, meiofauna are more abundant in most modern marine sediments, occupy a greater range of environments including oxygen-depleted environments, and have an impact on sediment biogeochemistry similar in magnitude to the macrofauna. However, almost nothing is known about their impact on ancient marine sediments because they leave few recognizable traces. Here we show, in Pliocene-aged sapropels from three sites in the Eastern Mediterranean, the first reported trace fossil evidence of meiofaunal activity and its relation to changing oxygenation.

The Pliocene sapropels are a classic low-oxygen facies commonly used as an analogue system for the widespread, high TOC black shales that characterise economically and oceanographically important intervals in the Palaeozoic and Mesozoic. We apply a novel imaging approach comprising back scatter electron (BSE) microscopy of Ar-ion polished samples to demonstrate that meiofauna comprehensively reworked the uppermost 3-4 cm of the sapropels under oxygen-depleted conditions that excluded macrofauna. The meiofauna fragmented and ingested organic laminae, emplacing 15-70 µm diameter (type A) faecal pellets without visibly influencing the macroscopic sediment fabric. Larger, 60-300 µm (type B) faecal pellets are restricted mainly to the upper cm of the sapropels studied. Chondrites trace fossils post-date meiofaunal activity and, unlike the faecal pellets, are readily identified by visual inspection.

Benthic nematodes are a common, widespread class of meiofauna in modern sediments, and are able to tolerate severely dysoxic and even sulfidic conditions. Nematodes from modern low-oxygen settings have body diameters closely corresponding to the size range of the type A faecal pellets, so that we interpret the concentration of type A pellets to be the product of marine nematodes living in and reworking the sediment during freshening phases of sapropel deposition. The size and ovoid shape of the type B faecal pellets, on the other hand, is more consistent with a small macrofaunal or large meiofaunal polychaete origin.

There are no documented examples of comprehensive meiofaunal reworking of marine sediments in the geologic record yet intervals featuring abundant, in situ benthic meiofaunal faecal pellets and fragmented OM laminae are present in Pliocene sapropels at all three sites studied. This raises the question: how common is meiofaunal reworking of sediments under low oxygen conditions that are prohibitive to macrofauna? While sapropels are commonly used as a model system for anoxic preservation of OM, are they also generally representative of meiofaunal modification that has as yet gone unnoticed in other fine-grained, high TOC sediments from low-oxygen environments?