Nano-scale Elemental Imaging of Microbes and Minerals from Deep Sea Methane Seeps

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Trace elemental compositions of sediment microbes remain largely uncharacterized due to the challenge of separating cells from mineral particles. Synchrotron x-ray fluorescence (SXRF) microscopy is one of the most sensitive techniques for quantitative trace element mapping of biological samples at nano-scale resolution. We performed SXRF imaging at 100 nm and XANES spectroscopy on thin sections of uncultivated microbial consortia that mediate anaerobic oxidation of methane. Samples included microbial aggregates enriched from Hydrate Ridge methane seep sediments. Sediment samples were incubated in the presence or absence of methane. The +methane treatment displayed two-fold higher sulfate reduction (assessed by sulfide production) than the –methane treatment. Of the 16 elements analyzed (Si, S, P, Cl, K, Ca, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn and W) only S, Ca and Cu were significantly elevated above background in the aggregates. Si-K-Ti-Fe-rich rings (Fig. 1) occurred around half of the DAPI-stained aggregates, consistent with previous findings (Dekas *et al*, in preparation). Abundances of S, Ca and Cu were elevated in aggregates from the +methane treatment compared to the –methane treatment. Given the low levels of Ni, Fe and other bioessential metals in microbial cells, it is possible that protein-bound metals were lost during sample preparation, and that the elevated S, Ca and Cu in cells may be mineral-bound, as supported by XANES data. While further sample optimization may be necessary to preserve metal cofactors within cells, this study demonstrates the utility of SXRF for nano-scale imaging of the elemental content of sediment microbes.

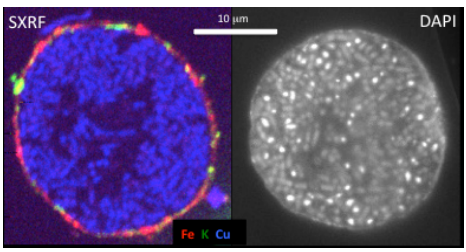

Figure 1. Corresponding SXRF (Fe=red, K=green, Cu=blue) and DAPI images of a microbial aggregate from the +methane treatment showing Fe-K-rich rings and enrichments of Cu in areas corresponding to DAPI-stained cells.