Sulfur Spectroscopy and Shipwrecks

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Wooden marine archaeological artefacts can be of great historical and cultural value, even though conservation of the complex material, degraded waterlogged wood infested with sulfur and iron compounds, is a difficult task. The anoxic conditions predominating at the seabed and in bottom sediments have often enabled high levels of preservation, as for the 17th century Swedish warship *Vasa* (Figure 1). Synchrotron-based sulfur K-edge x-ray absorption near edge structure (XANES) spectroscopy has made sulfur speciation possible for natural samples, and revealed when applied on the *Vasa* that totally several tonnes of reduced sulfur compounds had unexpectedly accumulated in the hull timbers, now with oxidation processes giving rise to severe acidity [1], see http://www.fos.su.se/~magnuss/.

For a number of historical shipwrecks XANES analyses, combined with x-ray fluorescence line scans along core samples, show that sulfur and iron compounds often have penetrated into the wood, reacted and accumulated in large quantities. Recent x-ray microprobe studies indicate that bacterially produced hydrogen sulfide formed iron sulfides and organosulfur compounds in the wood by different reaction pathways, aided by wood-degrading bacterial activity. Oxidation of the iron sulfides probably is the main cause of acidity in the wood, while the organosulfur compounds may be more resistant to oxidation. For lasting conservation, acid-forming sulfur compounds in the wood should be removed, if possible together with extraction of iron ions with a new efficient soluble chelate [2, 3]. For each unique marine archaeological object sulfur and iron scanning microprobe spectroscopy can be used to assess the need of specially adapted conservation procedures, to monitor the efficiency of the removal processes and the stability of the compounds remaining in the wood.

Figure 1: The *Vasa* after conservation treatment on display in the Vasa Museum.
Photo: Hans Hammarskjöld, the Vasa Museum

References

[1] - M. Sandström, F. Jalilehvand, I. Persson, U. Gelius, P. Frank and I. Hall-Roth, Nature 415, 893, (2002)
[2] - M. Sandström, F. Jalilehvand, I. Persson, U. Gelius and P. Frank, *SSRL Science Highlight*, Feb 2002, on the web: http://www-ssrl.slac.stanford.edu/research/highlights_archive/Vasa.html
[3] - *The Vasa's New Battle, Sulphur, Acid and Iron*, Sandström, M., Fors, Y. and Persson, I., Vasa Studies No. 19, The Vasa Museum, Stockholm, Ed. U. Djerw, Edita, Stockholm, 2003, 80 p