

Abiotic or bacterial degradation?

SHORT NOTE

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Comments on the paper by Čufar *et al.* 2008. “Anatomy, cell wall structure and topochemistry of water-logged archaeological wood aged 5,200 and 4,500 years” in IAWA Journal 29 (1), p. 55-68.

In this paper the authors describe and illustrate extensive cell wall degradation in old ash and oak wood buried in water-logged conditions for a long time. A typical feature was that the middle lamella appeared structurally intact, a feature that excludes pre-burial attack by white rot fungi. The authors concluded that the degraded “structures of the samples are consistent with abiotic rather than bacterial degradation”. This conclusion was based on the fact that their light and electron microscopic analyses showed no evidence of bacterial decay. We are convinced that most of the extensive degradation described has been caused by bacteria.

Before the 1990's it was commonly assumed that the degradation observed in wood after long time in water-logged condition was due to hydrolysis (Hoffmann and Jones 1990). However, no facts supporting this assumption have been presented. As far as we know there are no long lasting experiments where wood has been stored in water in the absence of micro-organisms. A large number of chemical analyses of water-logged archaeological wood have been published but the lack of simultaneous microscopical analyses makes it impossible to judge whether the degradation was abiotic or caused by micro-organisms. Chemical analyses of interior wood, not likely to have been affected by microbial decay, indicates that some abiotic degradation of hemicelluloses may occur. It is well known that the proportion of lignin increases relative to cellulose and hemicelluloses. This has led to the assumption that degradation of lignin occurs to a minor extent. However, where a mass balance in the chemical analyses was attempted, appreciable quantities of lignin were found to have been lost (Kohdzuma *et al.* 1996).

The lack of evidence for hydrolysis of wood by water at the conditions prevailing in the aquatic environments suggests that the effects would be minimal after a few thousand years.

Other abiotic processes known to degrade wood such as photo-oxidation, oxidation by Fenton type reactions or defibration by accumulation of certain salts are not likely to occur in water-logged environments. The authors of the paper do not provide any details of the chemistry of the water-logged environments which may have promoted abiotic hydrolysis. We conclude that the assumption by the authors, that abiotic processes were responsible for the degradation, is not based on known chemical processes but merely on the fact that no microscopic evidence was found for bacterial decay. Earlier reports by Hoffmann *et al.* (1986, 1990) where they assumed abiotic degradation of water-logged archaeological wood, were based on the lack of fungal hyphae and it should be noted that the reports were published before the time when bacterial degradation became common knowledge.

Bacterial attack is easy to recognise microscopically during the initial phases of attack. Bacteria can be seen to be attached to the cell wall where they cause erosion in the form of grooves (Daniel & Nilsson 1998; Klaassen 2008). In later stages of attack the compound middle lamella is seemingly unaffected,

whereas the secondary cell walls have been converted to a granular mass probably consisting of residual lignin, bacterial slime and remnants of erosion and scavenging bacteria (Björdal *et al.* 1999). The appearance resembles what is illustrated in several of the micrographs from the Slovenian material. Thus, the degradation described is consistent with bacterial degradation. Admittedly it is quite difficult at this stage to clearly see that bacteria have been involved in the degradation. One has to search where parts of the secondary cell walls remain. The bacteria are fragile and are likely to die and disappear through lysis when the substrate becomes exhausted. Even if bacteria could be seen, they cannot be recognised microscopically as erosion bacteria, when not seen actively degrading wood.

Over the years numerous papers have been published on bacterial degradation of water-logged wood. Thus, there is substantial evidence for such a process from quite diverse environments (Kim & Singh 2000). In addition, recent studies demonstrate that the erosion bacteria responsible for the degradation can be cultured in the laboratory (Nilsson & Björdal 2008). The use of such cultures have made it possible to reproduce the typical degradation patterns, a process that takes months rather than years. Active erosion bacteria have also been cultured from ancient wood samples, up to 2,000 years old (Nilsson & Björdal 2008). It seems highly unlikely that the site in Slovenia which contained the archaeological wood examined by Čufar *et al.* would be so totally different from other sites where bacterial degradation has been found to be the main cause of deterioration. It is possible that chemical processes also occur, particularly on the already degraded wood, but this remains to be proven. There is no doubt, in our opinion, that the major part of the degradation reported was caused by bacteria.

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