Wood, petrified by calcium-carbonate permineralization, in fossil spring tufas of the western Eastern Alps

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In the western part of the Eastern Alps, at three locations of fossil spring tufas characterized by aragonite and calcite precipitates, wood petrified by calcium-carbonate permineralization is present. Relative to its silicified counterparts, wood petrified in calcium carbonate is extremely rare (Martin, 1991).

Each tufa location is situated on a substrate of metamorphic rocks (quartz phyllite, phyllonitic gneiss, gneiss) that, in two cases, is veneered by (reworked) Würmian glacial till. In the field, the petrified wood fragments look closely similar to non-petrified wood, and show a light yellow to light ocre colour. Larger pieces of petrified wood in many cases show a more-or-less pervasive in situ-disintegration into fragments up to a few centimeters in length elongate parallel to the wood’s graining. The cell walls of petrified wood became replaced by micrite to microsparite, the cell lumina are filled by finely crystalline, lucid cement. The in-situ disintegrated, larger pieces of petrified wood consist of elongate fragments with well-preserved wood cell structure, separated from intercalated areas of microsparite with a clotted to „cloudy“ structure, locally with a few collapsed aggregates of wood cells. Alternatively, the areas intercalated between the fragments with well-preserved cell structure were open pores that became filled or are fringed by micrite and/or aragonite or calcite cement. In moss tufas, the leaves of moss plants became replaced by micrite to microsparite, whereas the stems of the plants left biomoulds that typically are filled by finely crystalline, lucid calcium carbonate cement.

For *silicified* wood, it has often been inferred that silicification is a geologically slow process. The presence of calcium-carbonate petrified wood in the fossil spring tufas, however, indicates that petrifaction may take place at very high pace. Wood and moss petrified by calcium carbonate to date were observed only at locations of fossil tufas with abundant aragonite. We assume that high supersaturation for calcium carbonate and abundant supply of supersaturated water had driven the petrifaction of wood by $CaCO_3$. That strong supersaturation and copious supply of supersaturated water does propel rapid petrifaction is supported by observations, by other authors, on silicification – within a few years – of wood in volcanic spring waters highly supersaturated for all polymorphs of silica. Th-U age data of aragonite cements yielded an age of 13.4 ± 0.2 ka (terminal Older Dryas) for

Gsalerweg and 10.4 ± 0.3 ka (earliest Holocene) for Flath-Alm. Because of high content of U and Th, the age deduced for the dated aragonite of each tufa occurrence is fairly precise; single-age calculations of sub-samples are close to the calculated age based on the slope of the regression line in Rosholt diagrams. At about 15 ka bp, the Alpine Würmian ice streams had decayed to the extent to allow for significant non-glacial deposition also within the Alps. This may hold in particular for the exposed, semi-arid inner-Alpine setting of Gsalerweg (13.4 ka), such that woody vegetation may well be expected there at the termination of the Older Dryas. For Flath-Alm (10.4 ka), the age is consistent with and adds to ^{14}C ages on the rise of timber line after the Younger Dryas in the Ötz valley, a few kilometers farther towards the east. There, at an altitude (1435 m) similar to that of Flath-Alm (1451 m), organogenic lake deposition rich in pollen of *Pinus* and *Betula* started at 10.235 ± 0.19 conv ^{14}C ka bp (Patzelt & Bortenschlager, 1978, cit. in Hantke, 1983, p. 133).

Our data show that active tufa-depositing systems that most probably were characterized by strongly supersaturated waters (leading to aragonite precipitation, and probably aiding in $CaCO_3$-permineralization of wood) existed very closely after glacial and interstadial climatic intervals, but today are fossil. A check of geological maps and own field observations indicate that presence of glacial till favours formation of tufa-depositing spring (see other contribution by Sanders et al. in this volume), but additional factors directly related to presence and melting of glaciers may be involved in producing a „tufa pulse“ immediately after glacials or marked glacial advance. More radiometric age data and more field investigations of tufas, however, are necessary to distinguish a genuine late Holocene „tufa decline“ (suggested by other authors) in the Eastern Alps from stratigraphic incompleteness as common to all depositional systems. Wood petrified by calcium-carbonate replacement in (fossil) tufa-depositing systems may be more widespread than previously recognized, and is notable not only for itself, but in combination with radiometric ages provides a new source to constrain vegetation history.

Hantke, R., 1983, Eiszeitalter: Die jüngste Erdgeschichte der Schweiz und ihrer Nachbargebiete. vol. 3, Ott, Thun, 730 pp.

Martin, R. E., 1999, Taphonomy. A Process Approach. Cambridge University Press, Cambridge, 508 pp.