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"Holocene human impact, climate and environment in the northern Central Alps: A geochemical approach on mountain peatlands"

Summary

Since the last deglaciation the European Alps have experienced several phases of human colonisation from different directions and societies. However, the interaction of climate, human impact and environment is still not fully understood in this high mountain region. In particular, information on the time and scale of human impact in the northern Central Alps (NCA) during the Holocene is missing. This study fills this gap by using geochemical, pollen and radiocarbon analyses in comparison to regional archaeological and historical data. Mires in three areas of the NCA were selected as study sites: Kleinwalser Valley (Vorarlberg, Austria), Piller Mire (Tyrol, Austria) and upper Fimba Valley (Grisons, Switzerland), situated in an altitudinal range of 1100 to 2400 m a.s.l.

These mires were cored and analysed. The use of geochemical proxies (lithogenic elements, trace metals) in peat is a well-established method to detect mineral input, erosion or metallurgical activities. Despite an advantage of a fast sample preparation and measurement, applying portable X-Ray-Fluorescence analysis (pXRF) on mountain mires is an uncommon approach, mainly due to limitations by low count rates, matrix effects or lacking calibrations for organic materials. By calibrating pXRF with measurements of quantitative Inductively Coupled Plasma – Mass Spectrometry (ICP-MS), these issues could be overcome, showing that, Ti, Pb, Sr, Zn, K, S, Fe, V, Zr, and - to some extent - Rb, Ca and Mn, can be successfully calibrated and used as palaeoenvironmental proxies in peat. These proxies allow the following conclusions:

At high elevations, periglacial processes influence the deposition processes in the mires. Around 8200 and in the late 7th millennium BP, wetter and colder climate conditions prevail in the region. The earliest land use is recorded in the Kleinwalser Valley around 5500 cal BP, with fire clearings, pastoralism and hints at previously undetected regional metallurgy. Just before the Bronze Age (c. 4300 cal BP), centuries before mining districts in the Eastern Alps boomed, metallurgy around the Piller Mire is detected. The possibly strongest human land use in prehistoric times affects all sites from the Mid to Late Bronze Age (3500-3000 cal BP), as shown by elevated erosion and significant landscape alteration – from forests to agro-pastoral

systems. Potential metal enrichments are, however, masked by high mineral inputs. This period is followed by a phase of lower land use, reaching well into the late Roman period (2800 cal BP to 250 cal CE). However, a strong Pb enrichment factor (Pb EF) in the Kleinwalser Valley is recorded around 2700 cal BP. Human impact increases in north-western Tyrol around 2400 cal BP. Periods of mining and metallurgy are indicated by increased Pb EF in all mires during the Roman Empire but also right after its collapse. Intensive human activities rise again with the fading Roman power after 250 cal CE in the Kleinwalser Valley but are interrupted by a climate deterioration after 500 cal CE (Late Antique Little Ice Age). At the sites in higher elevations, land use intensification does not take place before the High Middle Ages and is accompanied by rising Pb EF, indicating mining activities after 1000 cal CE. While Pb EF keeps rising due to mining, industrialisation and leaded fuel until 1980 cal CE, fluctuating human impact (deforestation, pasture management, drainage) can be linked to a varying impact of climatic, cultural and demographic factors. Over the last century, growing tourism and infrastructure construction increase erosion, but land use change leads to a recovery of the studied mires in Kleinwalser Valley and Tyrol.

The results of this study add a new dimension to archaeological and historical data, by showing the wider extent of human land use and its links to climate. Moreover, previously unknown periods of prehistoric mining or metallurgy in the NCA are revealed, encouraging further interdisciplinary research.