A geochemical study of lacustrine sediments: towards palaeo-climatic reconstructions of high Andean biomes in Colombia

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Citation for published version (APA):
Synthesis

This study has revealed that C₄ plant distribution holds important climatic information. Previously palaeo-vegetation reconstructions carried out in the Colombian Andes focussed primarily on pollen analyses, which is not able to discriminate between C₃ and C₄ grass pollen. Therefore vegetation changes between C₃ and C₄ grasses was largely unknown. The introduction of stable carbon isotopes and geochemical techniques have made it possible to explore the importance of these C₄ plants to the Andean palaeoecology. Moreover, it was aimed that this would contribute to an improvement of the existing reconstruction. It has resulted into new insights and a better understanding of modern day tropical high elevation vegetation. A mechanism was found that could explain the occurrence of C₄ grass paramo grasses such as Sporobolus lasiophyllus, at an elevation of 3500 meters. Previously this vegetation type was well known, but it had not been classified as a C₄ grassland. The cyclic reductions of atmospheric carbon dioxide concentrations that have been experienced during the glacial periods of the Quaternary are thought to have driven these C₄ grasses to higher elevations. Although this idea had been postulated earlier on for a site from Mt. Kenya in Africa, this was the first time that modern day remnants of this process had been identified. The use of fossil leaf lipids and compound-specific carbon isotope measurements yielded a detailed record of C₃/C₄ grass abundances. Ecophysiological and biogeochemical modelling has been used to transfer these result into a function of climatic parameters, from which atmospheric CO₂ concentrations could be reconstructed. This was an entirely novel and unique approach. It demonstrates that high sites at elevation in the tropics are important for palaeo-climate research, since this result could not have been obtained at any other location. Now there is potential at these specific sites to reconstruct long records of atmospheric CO₂ that can surpass the time span of famous ice-cores such as Vostok, by millions of years. Now that geochemical analysis have shown that C₄ plants are of importance for palaeo-climatic reconstruction, it is envisaged that other fields of palaeo C₄ plant research will be incorporated in future studies. The analysis of plant derived opaline silica bodies (phytoliths) can accompany geochemical analysis and would make a very powerful combination allowing detailed reconstruction of the grass ecosystem. There is also a strong need to investigate the importance of plants with crassulacean acid metabolism (CAM). These plants have always been largely ignored, while in Andean ecosystems they are often characteristic elements of vegetation. This thesis has attempted to make a start into the recognition of CAM plants into the geochemical world. Until today there is no means to identify CAM plant derived organic material in the geochemical record. Their isotopic compositions are usually somewhere in between that of C₃ and C₄ plants and therefore their contribution will generally be confused with a mixed input of these type of plants. With the novel observation that CAM plants have a resistant biopolymer in their cuticle, a chemical marker for CAM plants becomes available. Cutan will allow distinguishing, within the geochemical record, CAM plant organic matter from that of regular plants. Likewise, the structural
analysis of the megaspores of the aquatic CAM plant *Isoëtes* will allow us to use *p*-coumaric acid as a biomarker for these megaspores. Hence, new possibilities arise to study palaeo-distribution and isotopic characteristics of CAM plants. The *Isoëtes* sporopollenin could even be developed into a novel method to measure δ¹⁸O of this material. Several chemical steps would be required to account for, or to eliminate isotopic exchange of the carbonyl group, but once this is done, δ¹⁸O analyses on this material will give us the δ¹⁸O of the palaeo water. Until now this has not been possible, due to lack of inorganic carbon (which is usually used for this type of analysis) in the studied sediments. This could be the most valuable contribution towards the palaeo-environmental reconstruction after the CO₂ reconstruction.

Finally, the use of stable isotopes has provided more insight into the aquatic environment of the study area, an aspect that has been largely neglected until now. Blooms of *Botryococcus* algae in the ancient lacustrine environment near Funza have resulted in the worlds most “heavy” organic carbon molecules ever found. An isotopic closed system effect has caused this material, which is from pure biological origin, to be enriched in ¹³C to a degree that has never been observed in nature before. It is expected that these results from the Funza record will be recognised among the stable isotope community as the worlds most ¹³C enriched organic carbon.