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

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Summary

Chapter 1 introduces the main topics of this thesis. A detailed basic introduction to C₄ and CAM plants with relevance to Colombia in particular has been given here. This should be of relevance to anyone interested in Andean vegetation and in biogeochemistry of C₄ and C₃ plants in general. A list with C₄ and CAM taxa was compiled from literature and is representative for the study area. Theory of stable carbon isotope fractionation in plants is discussed and introduced as a tool to identify C₄ plant derived organic matter. A list with δ¹³C values of various Andean plant taxa is presented. In chapter 2 the theory that lowered atmospheric CO₂ concentrations may have caused low-land tropical C₄ grasses to migrate to higher elevations in the tropical Andes is introduced. δ¹³C measurements of organic matter from the high elevation Funza core support this idea. A discovery was made using modern day high elevation vegetation composition. Unusual C₄ grass paramo consisting of Sporobolus lasiophyllus exist up to elevations of 3500 meter. Other C₄ grasses such as Paspalum bonplandianum and several Muhlenbergia species fill the same ecological niche. These C₄ grass ecosystems are unusual since the majority of C₄ vegetation is strongly associated with warm conditions. It is proposed that these high altitude C₄ grasses are the remnants of ice age C₄ grass vegetation that once flourished on the high plain at times of low atmospheric CO₂ concentrations, and that have survived by adaptation to modern day conditions. This offers a mechanism to explain why certain plant taxa from the lowland tropics became paramo elements. This mechanism should have important implications for palaeoclimate reconstructions. These finding are further developed in chapter 3, where compound specific δ¹³C measurements on fossil leaf lipids from the Funza core, show that the abundance of C₄ plants has changed through time. A specific record could be reconstructed that quantifies C₃-C₄ vegetation change. However, the C₄ plants appear not to have gained complete dominance during a glacial period. Two antagonising driving forces of C₄ grass expansion in the Northern Andes, appears to have been lowering temperature and lowering atmospheric CO₂. Using an eco-physiological model of C₃ versus C₄ grass competition, the two forces could be separated. From existing palaeo-temperature estimates and C₄ plant cover percentages, palaeo-atmospheric CO₂ concentrations have been calculated. The result is surprisingly close to data of existing Antarctic ice-records such as the Vostok icecore, thus the competition model can explain the variations in C₃/C₄ plant input, and presenting a possible new method to reconstruct palaeo-atmospheric CO₂ concentrations.

The aquatic environment is investigated in chapter 4, which reports of the most ¹³C enriched natural organic material ever found on earth. This is an algal biomarker extracted from the Funza record. The chapter explores this unusual phenomena and tries to use it to put it into a palaeo-environmental setting of the ancient Funza lake. The algae Botryococcus, responsible for this unusual ¹³C enriched material, seems to have occupied a unique niche in the aquatic ecosystem. In this tropical high altitude lake, its lifestyle resulted in an unusual isotopic closed system effect, reducing
fractionation processes to virtually zero. These observations provide some new insights into palaeo climate and the palaeo-environmental history of the aquatic environment.

Chapter 5 and 6 deal with a more fundamental aspect of the geochemical investigations of the high plain of Bogotá. In order to study the palaeo-vegetation history of the area it is necessary to investigate in high details certain potential geochemical markers of vegetation components. The Funza record contains a lot of microfossils such as higher plant pollen and spores. One of the chemical substances that is highly resistant to microbial degradation is called sporopollenin, a substance found in pollen and spore walls. Some Andean sediments are exceptionally full of mega spore remains of the amphibious fern *Isoetes*, also the Funza sediments. Although not all spores might be preserved physically intact, its sporopollenin may be a potential biomarker for this particular plant. The sporopollenin of *Isoetes killipii* has been thoroughly investigated in this study. The major chemical building block of this particular biopolymer is p-coumaric acid. This is one of the few studies where sporopollenin has been isolated in this high purity. This information can be used to stable isotopic studies of fossil remains of *Isoetes killipii*. Although this was not done at this stage, this will provide extremely important information for reconstructions of the aquatic ecosystem. This biopolymer in this particular setting may turn out to be extremely useful as a tool to study the carbon chemistry of this aquatic CAM plant and to determine \( \delta^{18}O \) of the palaeo-lake, especially since carbonates are not present in many Andean sediments. Chapter 6 explores another higher plant biopolymer that is highly resistant to degradation. This macromolecule was subject to numerous geochemical studies. In this paper several entirely new examples of cutan occurrence are being reported. All clearly show the importance of these plants in the area of the Northern Andes. This paper has tripled the amount of known cutan containing plants, a new possible speculation on the function and further occurrence of this biopolymer is presented here. We conclude that it is especially the drought adapted plants, such as CAM plants wherein this biopolymer is found. Thus the occurrence of cutan in sediments can be further exploited and interpreted as palaeo-environmental indicator, further studies towards its occurrence in sediments will also be useful to enhance our knowledge on the history of such plants, which remains today still largely unknown, due to lack of fossils.