CONTINENTAL PAN SYSTEMS: NEW GEOARCHIVES FOR PALEOCLIMATIC RECONSTRUCTION IN ARID ENVIRONMENTS USING MICROBIAL BIOMARKERS

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Introduction

In arid southern African regions terrestrial climate archives are scarce impeding paleoclimate studies in this area. Previous geological studies based on Optically Stimulated Luminescence dating ages suggest that the sedimentary filling of continental pans might be appropriate geoarchives for Late Quaternary climate history (e.g. Telfer et al., 2009). However, it has never been proven before, whether this holds true for paleoclimate reconstruction based on organic biomolecules. Here we present a new approach to trace temporal and spatial changes in paleo-precipitation in arid environments by using microbial biomarkers as paleo-indicators. Water is a prerequisite for microbial life, thus, this study is based on the assumption that in arid areas increased abundances of microbial biomarkers in a paleo-record indicates periods of higher paleo-precipitation. To test our hypothesis we examined two different pans in the western (Omongwa pan) and south-western (Witpan) part of the Kalahari Desert. We applied a combined approach of molecular microbiological and biogeochemical lipid analyses to investigate the indigenous microbial communities in respond to modern and past climate induced environmental conditions. To understand former climate variations during the Late Pleistocene and Holocene in the western and south-western Kalahari we focused on depth-related variations in the abundance and composition of the microbial communities in pan sediments by using 16S rRNA high-throughput sequencing and characteristic microbial biomarkers for living (phospholipids) and past (glycerol dialkyl glycerol tetraethers, GDGTs) microbial life.

Results

The arid sediments of Omongwa pan and Witpan are characterized by low organic matter content and high concentration of sulphate and chloride especially in the top layers which contribute to the high salinity in the pan systems. The occurrences of microbial life markers (Phoshoplipid esters and ethers) indicate the presence of bacterial and archaeal life in both pans particularly in the surface deposits. This suggests that modern microbial life is strongly related to surface near processes. The high throughput sequencing approach revealed a specialized consortium of microorganisms, where Archaea comprise more than 30% of the community. Several bacterial and archaeal phyla were detected and halophilic and dry-adapted key taxa were found e.g., *Euryarchaeota*, *Gemmatimonadetes*, *Bacteroidetes*, *Proteobacteria*, and *Actinobacteria. Euryarchaeota* sequences were mainly related to *Halobacteria*.

Past microbial biomass was predominantly indicated by dialkyl glycerol diethers (DGDs, e.g. Archaeol also with a C_{25} side chain) representing characteristic biomarkers for halophilic Archaea. Additionally, branched GDGTs (brGDGTs) representing typical biomarkers for *Bacteria* (Weijers et al., 2007) and isoprenoid GDGTs (iGDGTs) being characteristic markers for *Archaea* (Schouten et al., 2013) occurred in smaller amounts. Below the surface sediments past microbial biomarkers are low or absent in both location during the Holocene sequence. In contrast, during the Late Pleistocene a significant increase of past microbial biomarkers can be observed. While changes was determined at the transition to the Holocene at Omongwa pan, at Witpan changes was recorded during the Last Glacial Maximum (LGM). Paleoclimate informations from the Witpan region suggest a dry Holocene period and wetter conditions during the LGM. This information fits well with the observed past microbial marker distributions indicating that in arid environments microbial biomarkers in continental pan systems preserve a paleo-precipitation signals over geological timescales. Transferring this finding on the microbial biomarker depth distribution in Omongwa pan it can be deduced that in the western Kalahari wetter conditions occurred later than in the south-western Kalahari.

Conclusions

The life marker data shows that surface near processes seem to play an important role for the modern microbial ecosystem in the pans. Water availability and salinity determine the abundance and composition of the microbial communities in these arid to semi-arid environments. We could indicate higher species diversity in the near surface sediment compared to deeper layers. Near surface sediments, where water is at least occasional available, are attributed to fast changing conditions and may represent an important refuge for phototrophic and chemo-heterotrophic *Bacteria* as well halophilic *Archaea* (*Halobacteria*).

Our new approach showed that past microbial biomarkers can be used to trace precipitation history in arid to semi-arid regions in the Kalahari. Low or absent biomarkers for past bacterial and archaeal life during the Holocene sequence are considered to represent a dry period in our study areas. In contrast, during the Late Pleistocene period higher abundance of past microbial life seems to reflect periods of increased paleo-precipitation. Precipitation in this region is controlled by the seasonal shift of the Intertropical Convergence Zone (influencing the summer rainfall zone) and the northward migration of the Southern Hemisphere Westerlies (influencing the winter rainfall zone). Our data support a period with higher paleo-precipitation during the Last Glacial Maximum (~21 ka BP) for the south-western Kalahari, due to an expansion of the winter rainfall zone caused by a northwards migration of the Westerlies. However, this northward extension did not influence the western Kalahari, where wetter conditions are indicated later during the transition from the Last Glacial to the Holocene between 17 and 12 ka BP. The increase in precipitation in the western Kalahari is most likely attributed to stronger trade winds, which were caused by a more landwards shift of the summer rainfall zone.

Overall, it was demonstrated for the first time, that in arid to semi-arid regions microbial biomarkers have the potential to act as indicators for the reconstruction of paleoclimatic conditions and that pan systems can represent appropriate geoarchives for biomolecules in dry areas, where other terrestrial records are rare.

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