Report:
Hydrogen isotopic composition of soil bacteria membrane lipids as recorders of past precipitation dynamics

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Purpose of the visit

Past research has shown that the distribution of branched glycerol dialkyl glycerol tetraether (GDGT) lipids, molecules that are derived from bacterial membranes and are ubiquitously present in soils worldwide, reflects the climatic conditions of the organism's living environment. Their distribution and relative abundance in sedimentary archives have been used to reconstruct of past continental temperature dynamics.
During the past decade, compound-specific hydrogen isotope analysis (δD) of lipid biomarkers has been implemented as a proxy for changes in the hydrological cycle. Since the hydrogen isotopic composition of a specific biomarker is related to the moisture source for the biological precursor organism, the δD-value of branched GDGTs reflects local hydroclimate experienced by soil microorganisms.
Due to their high molecular weight and relatively low volatility, determination of the isotopic composition of branched GDGTs requires chemical degradation in order to render the lipids amenable to gas chromatographic separation. At ETH Zurich, such a method for chemical treatment is currently being tested and applied to environmental samples with different isotopic composition.
Statistically known as 'the wettest place on Earth', the Cherrapunji plateau in Megalaya, North-Eastern India is a region of strong scientific interest. A better understanding of past precipitation dynamics in the area helps to improve the knowledge of the Indian summer monsoon system.

The hydrogen isotopic composition of precipitation and therefore the compound specific δD-value of lipid biomarkers is influenced by the moisture source area of the precipitation, by its amount ('amount effect') and by altitude ('altitude effect'). Strong gradients both in precipitation amount and altitude make Cherrapunji an excellent setting to study the influence of the mentioned factors on the hydrogen isotopic composition of branched GDGTs.

During the field work, which has been carried out in strong cooperation with Dr. Syiemlieh from the North Eastern Hill University (NEHU) in Shillong, two sampling projects were realised. Surface soil samples have been collected along an altitudinal transect from the plateau down to the lowlands at the border of Bangladesh. Furthermore, two peat bogs have been sampled with the aim to study changes in the amount of the precipitation over time.
By choosing the month of May just before the start of the monsoon season as travel time for our visit, it was possible to realise both projects. We experienced some precipitation events and collect surface soil samples containing high soil moisture but were still able to sample peat profiles. Due to the rising water level, it is logistically more complicated to enter the peat bogs during monsoon season.

Description of the work carried out during the visit

During the two week visit at the Geography Department of the North Eastern Hill University (NEHU) in Shillong, we were able to collect soil samples for biomarker-analysis at different locations on the Cherrapunji plateau. The area is located south of Shillong, capital of the state of Meghalaya.

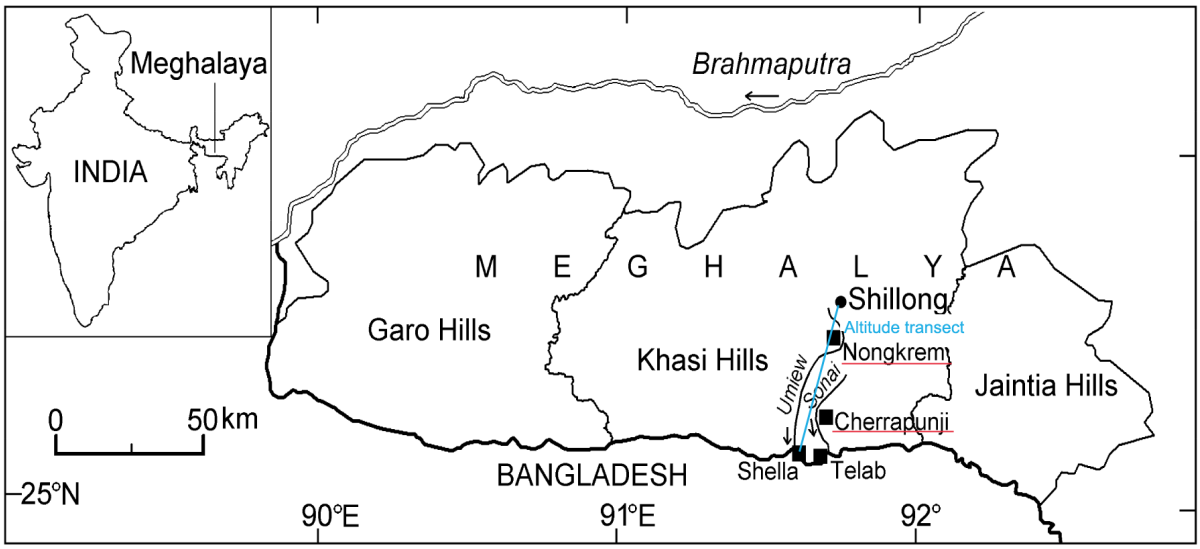

Fig. 1: Map of the state of Meghalaya, the altitudinal transect along which surface soil samples were collected (blue) and the location of the two sampled peat bogs (red) (Prokop et al., 2011).

North of the boarder of Bangladesh, the plateau quickly raises up to approximately 1000m altitude. Several valleys with steep slopes interrupt the flank. The plateau continues to rise towards the city of Shillong on the backside of the plateau, with its highest point being Shillong peak at 1966m altitude.
The work that has been carried out during the visit consists of two parts: the collection of surface soil samples along an altitudinal transect at the southern slope of the plateau (1) and the sampling of two local peat bog profiles (2).

1. Surface soil samples along an altitudinal transect

In order to study GDGT lipids with different isotopic composition due to the altitude effect, surface soil samples were collected at varying height above sea level. Starting at an altitude of 28 meters close to the border of Bangladesh, samples were collected at every 100m height difference, up to a highest sampling location at 1865m close to the city of Shillong.

The samples are expected to show the present day precipitation signal, with differences in the hydrogen isotopic composition of its branched GDGT molecules due to the altitude effect. Because of a higher molecular weight, the heavy hydrogen isotope deuterium rains out faster than the normal hydrogen isotope, leading to an enrichment (positive δD-value) at lower altitude with the beginning of orographic rainfall. With the aim to test for the described effect, approximately 100g of material were collected at each of the sampling locations.

a b

Fig. 2: View of the crest of Cherrapunji plateau down towards the lowlands of Bangladesh (a), typical sampling location of the surface soil samples along an altitudinal transect (b).

2. Peat bog profiles

To study changes of precipitation in Meghalaya over time, two peat bogs on the Cherrapunji plateau were sampled. Peat bogs have been shown to be valuable archives of GDGT lipids due to their high content of organic material.

The isotopic composition of branched GDGTs is expected to change over time due to the amount effect: the content of the heavy hydrogen isotope deuterium decreases with an increasing amount of rainfall, leading to a depleted δD-signal. The hydrogen isotopic composition of the branched GDGT molecules and its δD-value respectively may therefore be used as indicator for past precipitation changes.

The samples peat bogs are:

- Peat bog Cherrapunji, located East of the town Cherrapunji (N25°15'51.3'', E091°43'27.6''). The peat bog has been dated before and shown to cover the time period of the Holocene (Prokop et al., 2011). The depth profile was sampled along a slope at the side of a creek.
- Peat bog Nongkrem, located in the South-West of the town Nongkrem (N25°28'29.7'', E091°52'12.5'') has not been sampled before. The depth profile was sampled with a peat corer.

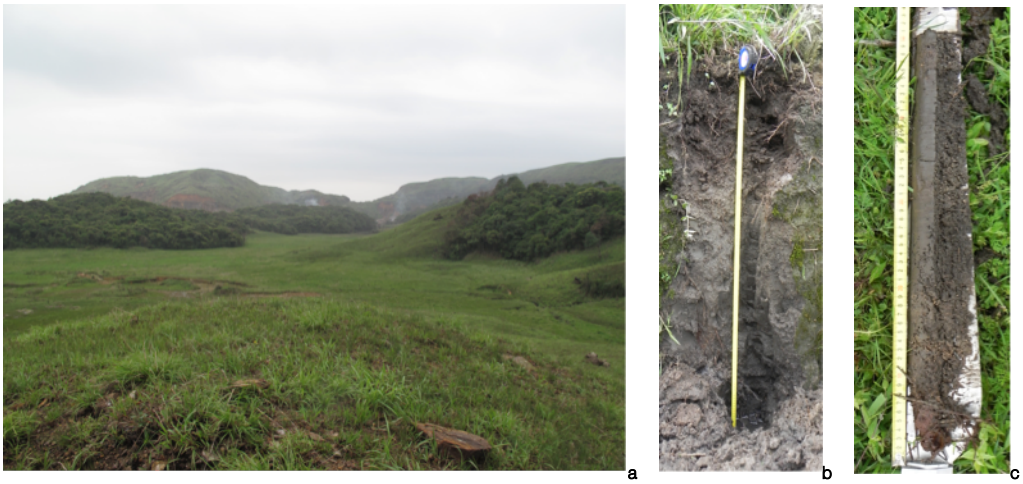

Fig. 3: The location of the Cherrapunji peat bog (a), peat bog profile of Cherrapunji (b), sampled along a slope and peat bog profile Nongkrem (c), sampled using a peat corer.

Description of the main results obtained

The surface soil samples along an altitudinal transect and the peat profile samples have been transported to ETH Zurich for laboratory analysis. The branched GDGT lipids are currently getting extracted and chemically degraded in order for their isotopic composition to be analysed using gas chromatography and mass spectrometry.
The soil samples are expected to show a more positive δD-value (deuterium enrichment) at low altitude. From the peat bog profiles we will gain information on past precipitation changes.

Future collaboration with the host institution

With the use of the hydrogen isotopic composition of branched GDGTs as indicator for past changes in precipitation currently being tested, further application of the developed method to environmental samples has great potential.
The region of the Cherrapunji plateau, with its strong seasonality in precipitation and a generally very high annual precipitation amount would be especially interesting for further paleo-precipitation studies. As the hydro-climate of the region is strongly influenced by the Indian summer monsoon, it is optimally located for reconstruction of past dynamics of the meteorological system. Aim of such project is to reach a better understanding of the historical development of the Indian summer monsoon system.
A collaboration with the Geography Department of NEHU allows further localisation of undisturbed peat bogs that have the potential to be used as climatic archives.

Projected publications resulting or to result from the grant

The data that is generated from the collected samples will be presented at the 5th International Workshop on Soil and Sedimentary Organic Matter Stabilization and Destabilization (SOM-5) in Ascona, Switzerland from the 7th to 12th of October 2012.
After completion of the dataset, a manuscript on the use of the hydrogen isotopic composition of lipid biomarkers as indicators for paleo-precipitation as well as changes in the δD-value of branched GDGTs along an altitudinal transect will be prepared for publication in a peer-reviewed journal.