Hydroclimatic variations from the Last Glacial to historical times in the eastern Lesotho Highlands, southern Africa

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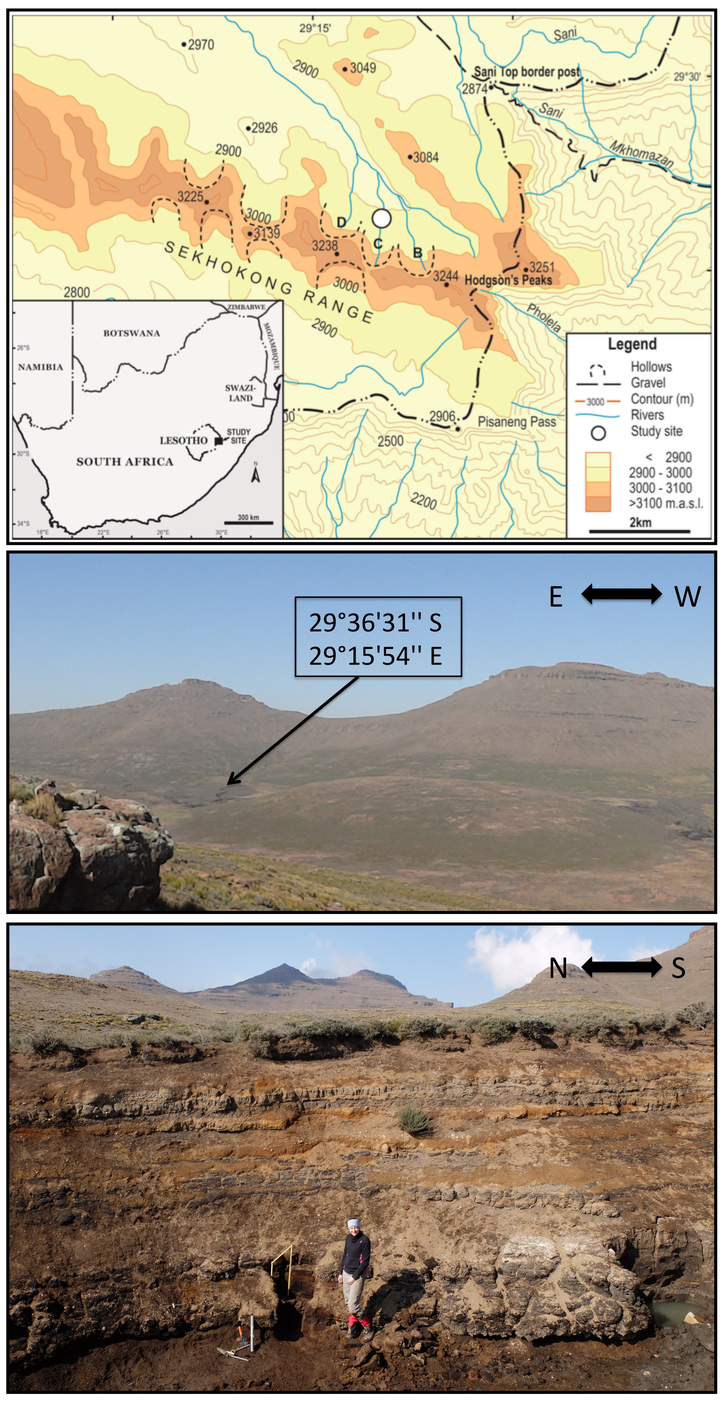
Introduction

Paleoclimatic changes during the Late Glacial are not yet resolved for southern Africa and there is a need for well dated, high-resolution long-time climate records. Lesotho is one of the most important water resources in southern Africa. It is thus critical to understand how climate controls the hydrology of the region. This study, which is part of a larger project that spans from the Late Glacial to present, focuses on a period (17.3 kyr BP to 13.3 kyr BP) where significant hydroclimatic variability is suggested by a suite of geochemical proxies.

Aim

Using multiple geochemical data sets the aims are:

- Identify processes controlling the geochemical signature of the studied sequence, such as weathering, sediment movement and transport, biological productivity, degradation and source changes.
- Reconstruct the paleohydrology.



Materials and methods

In May 2016, sediment samples were taken from the lower part of a gully in the Sekhokong mountain ranges, Lesotho (see map[1]), where over 4 meters of the deposit has been exposed. Sampling was done from the gully sidewall and by Russian corer.

Analysis:

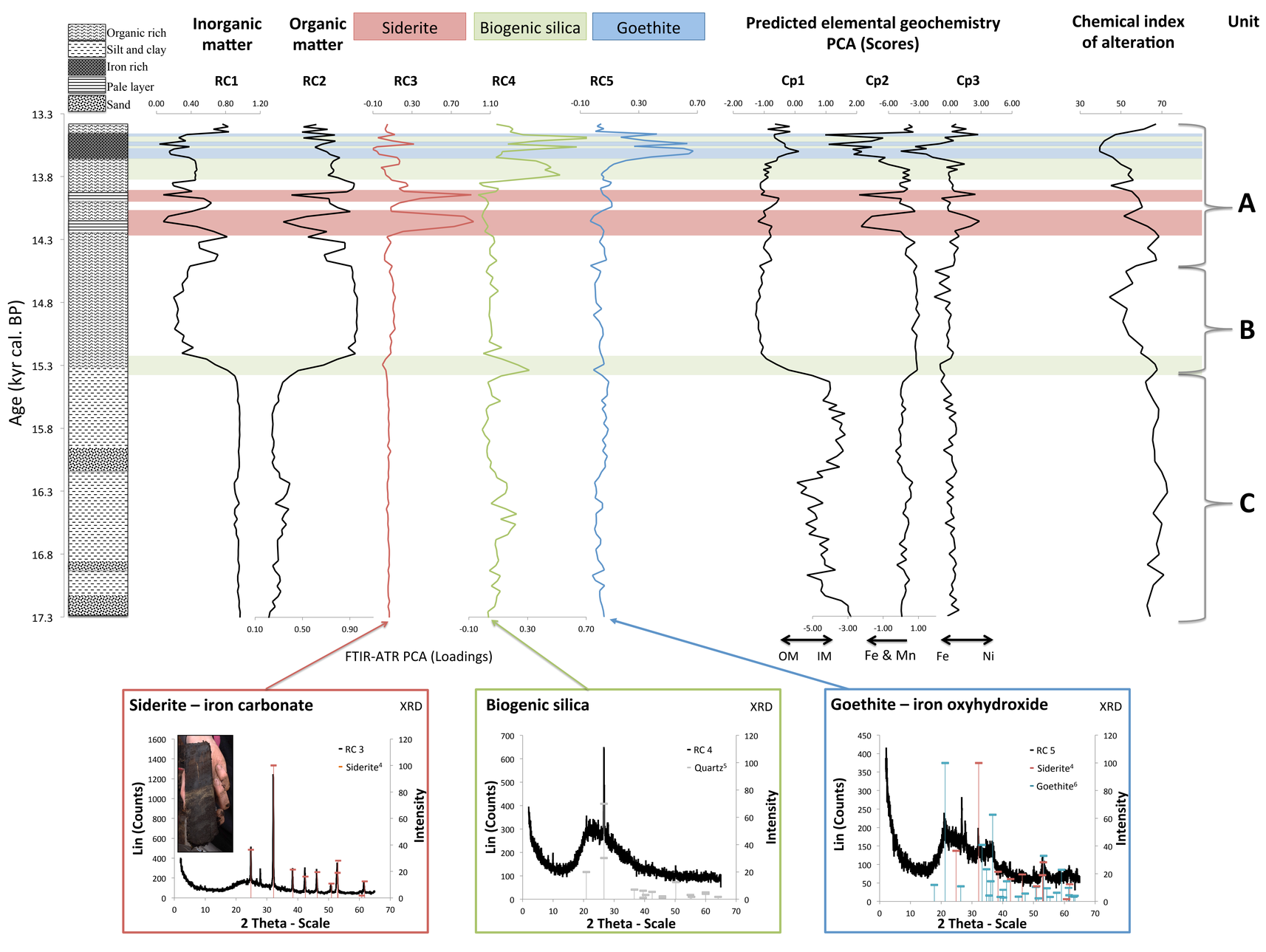
- Conventional and core-scanning X-ray fluorescence (XRF)
- Loss on ignition
- Elemental analysis ($\delta^{13}C$, total organic carbon and total nitrogen)
- Fourier transform infrared – attenuated total reflectance (FTIR-ATR)
- X-ray diffraction (XRD)
- Pyrolysis gas chromatography-mass spectrometry

Data handling:

- Principal component analysis (PCA)
- Multiple linear regression (MLR)
- Chemical index of alteration[2]:
  $CIA = (Al_2O_3/Al_2O_3+CaO^*+Na_2+K_2O) \times 100$

Results and preliminary interpretation

Based on the statistical analysis of two independent datasets (FTIR-ATR and predicted elemental geochemistry data), three main units were defined to represent the major environmental shifts. The five components (97% of the variance) extracted from the PCA of the FTIR-ATR data were interpreted to represent inorganic matter, organic matter, siderite, biogenic silica, and goethite inputs. XRD data identifying siderite, biogenic silica and goethite confirms this interpretation. The first component (Cp1) extracted from the PCA on the predicted elemental geochemistry data explains 75% of the variance with positive/negative loadings for elements associated with inorganic/organic matter. Negative values in Cp2 (14% of the variance) show an increase in Fe and Mn. Positive values of Cp3 (3% of the variance) indicate an increase in Ni with respect to Fe. The chemical index of alteration indicates the input of mobile elements in relation to immobile elements; negative values represent more mobile cations in the deposit and higher chemical weathering in the drainage area. The chemical index of alteration is strongly correlated to the first principal component (RC1) extracted from the FTIR-ATR data, r=0.88.



Unit	Sediment	Processes	Conditions
A 13.3-14.5 kyr	• Organic matter-rich layers • Diatom layers • Siderite layers • Goethite (low crystallinity) layers	• Autochthonous biological productivity • Allochthonous input of cations due to relatively high chemical weathering • Siderite precipitation, favoured by reducing conditions and high CO_2 pressure • Siderite dissolution and replacement by goethite	• Unstable climate • Dry/drought ↔ wet conditions • Low ↔ high water tables
B 14.5-15.3 kyr	• Organic matter – Dominated by aliphatic, polysaccharides and humic compounds – No real lignin found, high alcohol abundance – $\delta^{13}C$ values < -25 – C/N ratio around 15 – Originates from semiaquatic vascular plants and/or mosses.	• High autochthonous biological productivity • Allochthonous input of cations due to relatively high chemical weathering	• Relatively warm and wet • High water tables
C 15.3-17.3 kyr	• Inorganic sediment – Dominated by silt and clay – Layers of sand and low abundance of gravel. • Low concentrations of well preserved organic matter	• Allochthonous input of inorganic matter • Low biological productivity • Relatively low chemical weathering	• Relatively cold and dry • Low water tables

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