Suitability of Paleosols from the early Miocene Kiahera Formation, Rusinga Island, Kenya for Stable Isotopic Analysis

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ABSTRACT

Climate change and concurrent environmental changes play an important role in understanding biological evolution through time, because climate change may be a stressor that promotes flora and fauna adaptations. Nearly a century of geological and paleontological study on Rusinga Island, Lake Victoria, Kenya, has made it a touchstone for understanding early Neogene floral and faunal evolution. This is because sediments that were deposited between ca. 20-17 Ma, during the early Miocene, are famous for the presence of the early ape, *Ekembo,* as well as more than 100 species of mammals. The basal Kiahera Formation has largely been understudied, but recent preliminary work suggests it contains an abundance of fossil soils (paleosols), as well as uniquely preserved fossils. Here we report on the clay mineralogy of four different paleosols within the Kiahera Formation using x-ray diffraction (XRD) analysis. Preliminary XRD analysis reveals samples dominated by illite, kaolinite, and mixed layer clay minerals. In particular, sample LM17KF contained an abundance of clay minerals, no evidence of diagenetic alteration, and the desired two clay mineral suite of illite and kaolinite. This sample was determined to be the most robust candidate for future stable isotopic analysis. These results advance our ability to quantitively assess climate on the island, particularly in a formation that is important for its small mammal communities. Furthermore, this work, suggests there are phyllosilicates that are appropriate for $\delta^{18}O$ analysis which may result in our better understanding the role the East African monsoon played in the environment during this time.

BACKGROUND AND METHODS

East Africa is a hotspot for research on early ape evolution as a result of its rich fossil record. However, fossils are not enough to fully understand how and why certain evolutionary traits develop. To fully understand evolution one must examine the driving forces for these adaptations to take place. One major force for adaptation is the climate, climate change then causes stress which causes evolution. Today much of East Africa is controlled by fluctuations in rainfall associated with movement of the intertropical convergence zone (ITCZ; Figure 1). During the northern hemisphere summer, the southeasterly Tradewinds deliver wet air masses from the Indian Ocean (Figure 1A; Nicholson, 1996). During the northern hemisphere winter, dry air masses are sourced off of the Arabian plate (Figure 1B). However, there has been little work to investigate when this wind pattern and resulting precipitation style began.

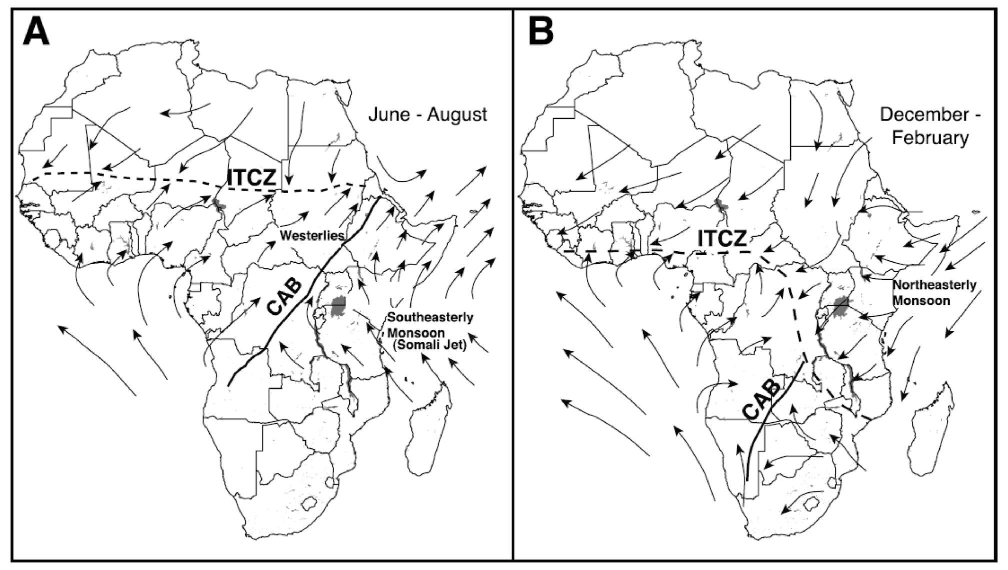

Figure 1. Low-level mean wind directions in African today (from Levin et al., 2009; adapted after Nicholson, 1996)

Most of the previous research on Rusinga Island has focused on the fossiliferous Hiwegi Formation (Figure 2), with recent work suggesting the paleoenvironment fluctuated between more open to closed (Michel et al., 2020). One possibility for these environmental fluctuations may have been changes in the intensity of seasonality, which today is controlled by the monsoon where water sourced from the Indian Ocean travels across Kenya. Prior to the setting up of the East African Monsoon, air masses would have been sourced from the Atlantic or Tethys Oceans. Paleosols from the older Kiahera Formation (Figure 2) which contain macroscopic evidence of seasonality (Figure 4) may be used to fingerprint the source of the air masses during the early Miocene.

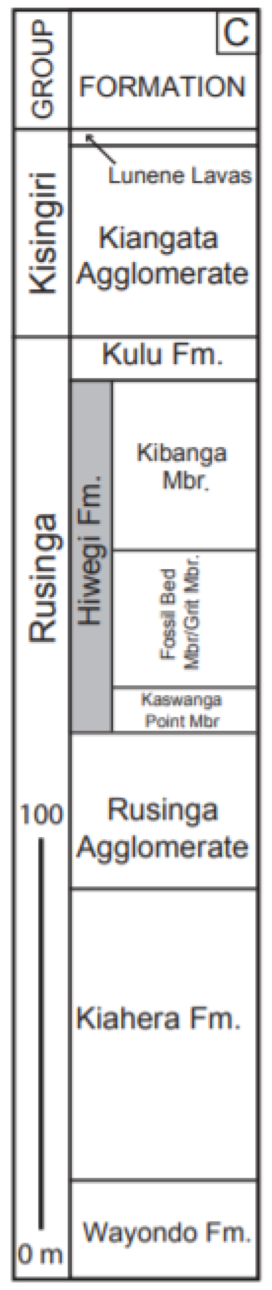

Figure 2. Stratigraphic column of early Miocene rocks on Rusinga Island (after Michel et al., 2020).

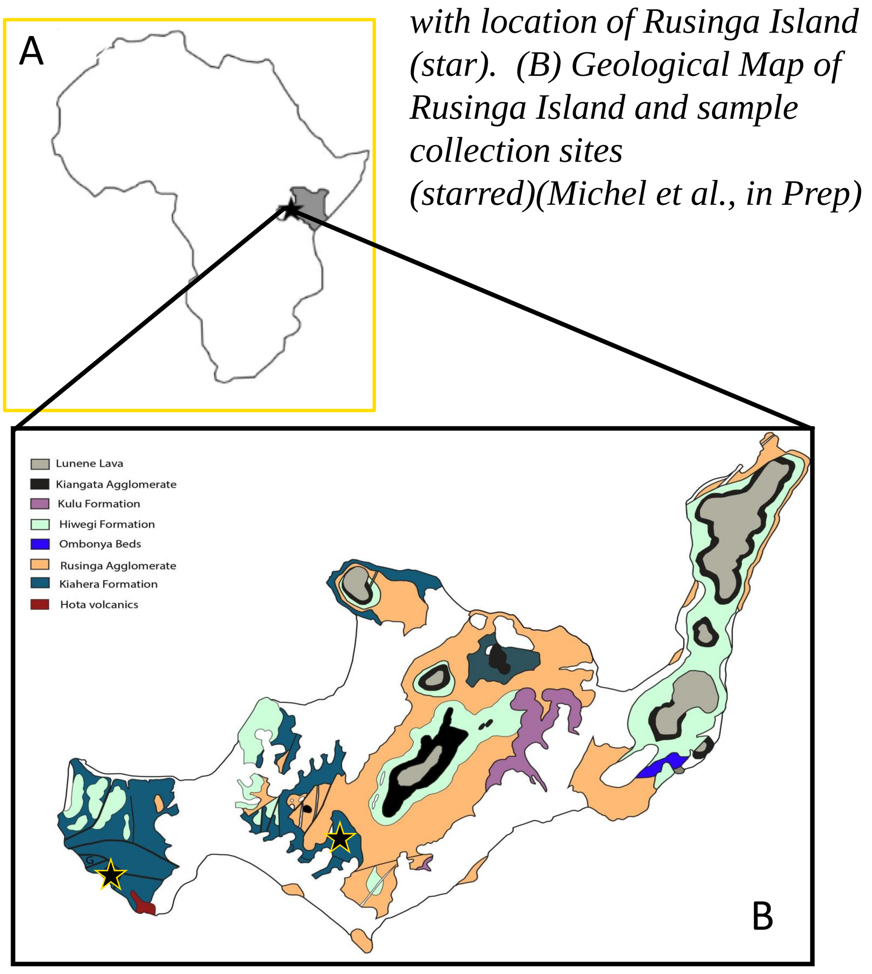

Figure 3. (A) Map of Kenya with location of Rusinga Island (star). (B) Geological Map of Rusinga Island and sample collection sites (starred)(Michel et al., in Prep)

Between 2017-2019, several fossil soils (paleosols) were described and sampled for a variety of analyses from a number of Kiahera Formation locations across Rusinga Island (Figure 4). Samples were brought back to Kittrell Hall for storage. Samples were disaggregated in deionized water (d.i.) using ultrasonic agitation. The <2 µm and <0.2µm equivalent spherical diameter (e.s.d.) size fraction was isolated via centrifugation before a four-step salt solvation technique using oriented aggregates was employed. This methodology is outlined in Moore and Reynolds (1997). The oriented aggregates were then analyzed with a Panalytical X-Ray Diffractometer housed in Henderson Hall. The data from the XRD analysis (Figure 5) was then used to identify the clay mineralogy present in each sample. The sample with the desired clay mineralogy was then subjected to the beginning stages of clay mineral isolation through flocculation and acid digestion as outlines by Tabor and Montañez (2005).

Figure 4. Paleosol sampled from the Kiahera Formation. Slickenside (red box) in Vertisol found in the upper member of the Kiahera Formation. Cloth bag shows sample collected for stable isotopic analysis.

RESULTS

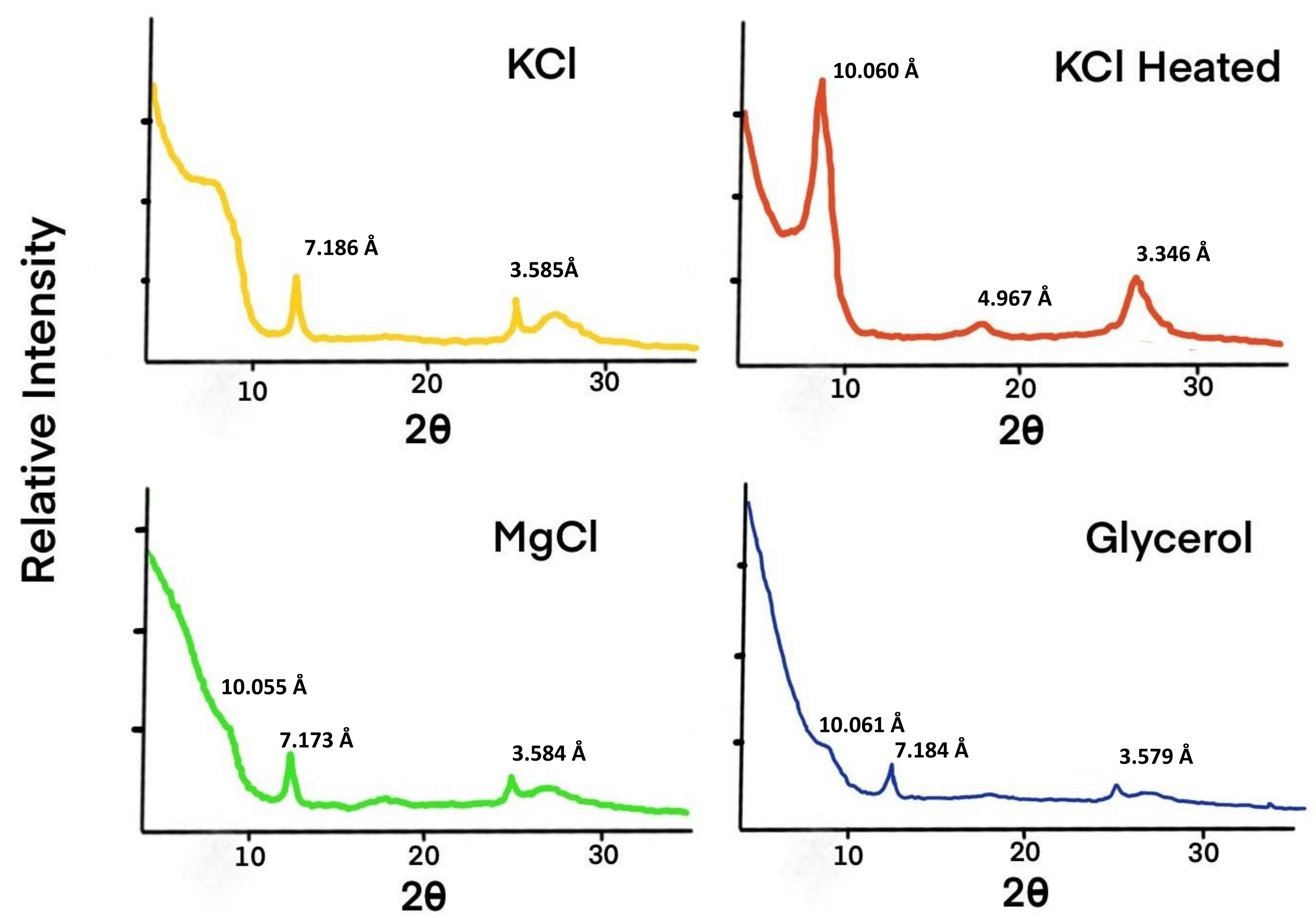

Figure 5. XRD results for sample LM17KF from the Kiahera Formation. Each color represents a different treatment with yellow representing a KCl treatment; red heating the KCl treated samples to 500˚C; green representing a MgCl treatment; and blue representing McCl + a 4:1 Glycerol treatment.

The ~7Å and ~3.5Å (a harmonic of the ~ 7Å peak) peaks seen in the KCl treatment collapse upon heating which suggests the presence of kaolinite.
Heating the KCl aggregate causes an expansion at ~11Å and ~5Å which supports an interpretation of illite in the sample.

CONCLUSIONS

XRD analysis of the paleosols sampled in the field reveals a complex mineralogy of illite and kaolinite, with some samples also containing smectite. Sample LM17KF has an abundance of illite and kaolinite. Previous research shows that this mineralogy is both suggestive of both modern soil-forming processes and having appropriate composition for stable isotope analysis (Tabor and Montañez, 2005). This study provides support that stable isotopic analysis of phyllosilicate minerals can be performed in Kiahera Formation paleosols.

FUTURE GOALS

- Proceed with acid digestions of best sample to remove non-silicate minerals.
- Analyze the sample, LM17KF, to determine the $\delta^{18}O$ and δD values for the fine-clay fraction minerals.
- Plot stable isotope data to create a local meteoric water line to determine the possible source of precipitation.
- Provide meaningful data to support the onset of current-day wind patterns.

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CITATIONS

Levin, N.E., Zipser, E.J., Cerling, T.E. (2009). Isotopic composition of waters from Ethiopia and Kenya: Insights into moisture sources for eastern Africa. *Journal of Geophysical Research* 114(D23306). doi: 10.1029/2009jd012166.
Michel, L. A., Lehmann, T., McNulty, K. P., Driese, S. G., Dunsworth, H., Fox, D. L., Harcourt-Smith, W.E.H., Jenins, K., and Peppe, D. J. (2020). Sedimentological and Palaeoenvironmental study From Waregi Hill in THE Hiwegi formation (early Miocene) ON Rusinga island, Lake Victoria, Kenya. *Sedimentology* 67(7), 3567-3594. doi:10.1111/sed.12762
Michel, L.A., Peppe, D.J., Lutz, J.A., Driese, S.G., Dunsworth, H.M., Harcourt-Smith, W.E.H.,, Horner, W.H., Lehmann, T., Nightingale, S., and McNulty, K.P., (2014). Remnants of an ancient forest provide ecological context for Early Miocene fossil Apes. *Nature Communications* (5) 3236. doi:10.1038/ncomms4236.
Moore, D. M., & Reynolds, R. C. (1997). X-ray diffraction and identification and analysis of clay minerals. pp, 378, Oxford University Press, Oxford.
Nicholson, S.E., (1996). A review of climate synamics and climate variability in eastern Africa, in *The Limnology, Climatology, and Paleoclimatology of the East African Lakes,* edited by T.C. Johnson and E.O. Odada, pp. 25-56, Gordon and Breach, Amsterdam.
Tabor, N. J., Montañez, I. P. (2005). Oxygen and hydrogen isotope compositions of Permian pedogenic phyllosilicates: Development of modern Surface Domain arrays and implications for paleotemperature reconstructions. Palaeogeography, Palaeoclimatology, Palaeoecology, 223(1-2), 127-146. doi:10.1016/j.palaeo.2005.04.009