A terrestrial reconstruction of Gona, Ethiopia before and during the African Humid Period

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Abstract

The African Humid Period (AHP) resulted in more humid conditions across Northern and Eastern Africa from 15 to 5 thousand years ago (ka). This wetter climate affected flora, fauna and the *Homo sapiens* living in East Africa. The lack of terrestrial paleoenvironmental reconstructions is a problem in East Africa, especially during the AHP, where most are done utilizing lacustrine or marine proxies. In the case of Gona, Ethiopia, terrestrial proxies are desired due to the rich archaeological and fossil concentrations that occur in the area. Paleosols provide more direct, localized reconstructions that provide context for these finds. This study utilizes paleopedology, geochronology, and geochemistry to reconstruct the environment of Gona during the AHP.

We examine paleosols from the Erole and Odele drainages within Gona. The Odele paleosol weathered before the AHP, between the Korina Tuff (<39 ka) and the Kilaitoli Tuff (~25.7 ka). The Erole paleosol is above the Kilaitoli Tuff and immediately above a calibrated ^{14}C age of 12 ka. These paleosols formed in floodplains of tributaries that flowed into the nearby Awash River. Strain calculations show more volumetric collapse at Erole (-39 ± 8 %) than at Odele (-5 ± 4 %). The open-system mass-transfer coefficient, tau, shows average losses of 25 ± 13 % SiO_2 and 71 ± 6 % CaO at Erole, which are greater than losses of 8 ± 4 % SiO_2 and 7 ± 3 % CaO at Odele. These calculations suggest more weathering and dissolution of minerals during the AHP, as well as more bioturbation. The results of this paleosol comparison are consistent with wetter conditions during the AHP that facilitated the development of grasslands along tributary valleys.

Background

- The African Humid Period (AHP) spanned 15-5ka
  - Associated with warmer, wetter conditions across Northern and Eastern Africa (Costa et al., 2017)
- The role climate change has on early human dispersal is not well understood
  - It is proposed the AHP is responsible for the onset of pastoralist practices and facilitated human expansion in the Sahara (Chritz et al., 2019)
- East Africa lacks terrestrial paleoenvironmental reconstructions
  - Very few exist for the AHP
  - Most are marine or lacustrine
- Paleosols provide a direct, localized terrestrial environmental reconstruction
- Gona, Ethiopia's Upper Busidima Formation (Fig. 1a,b) contains paleosols that formed during the AHP (Quade et al., 2008)

Research Questions

- What was the African Humid Period like at Gona, compared to the Last Glacial Period (LGP)?
- What resources were available to *Homo sapiens* during the AHP?
  - Water availability?
  - Resource abundance and diversity?

Methodology

- Paleosol and sedimentological description and sampling in the field
  - Color, texture, carbonate content, presence of slickensides
- Lab analysis for bulk density
- Geochemical data via X-ray fluorescence
  - Application of geochemical mass-balance coefficients as established by Brimhall et al., 1991

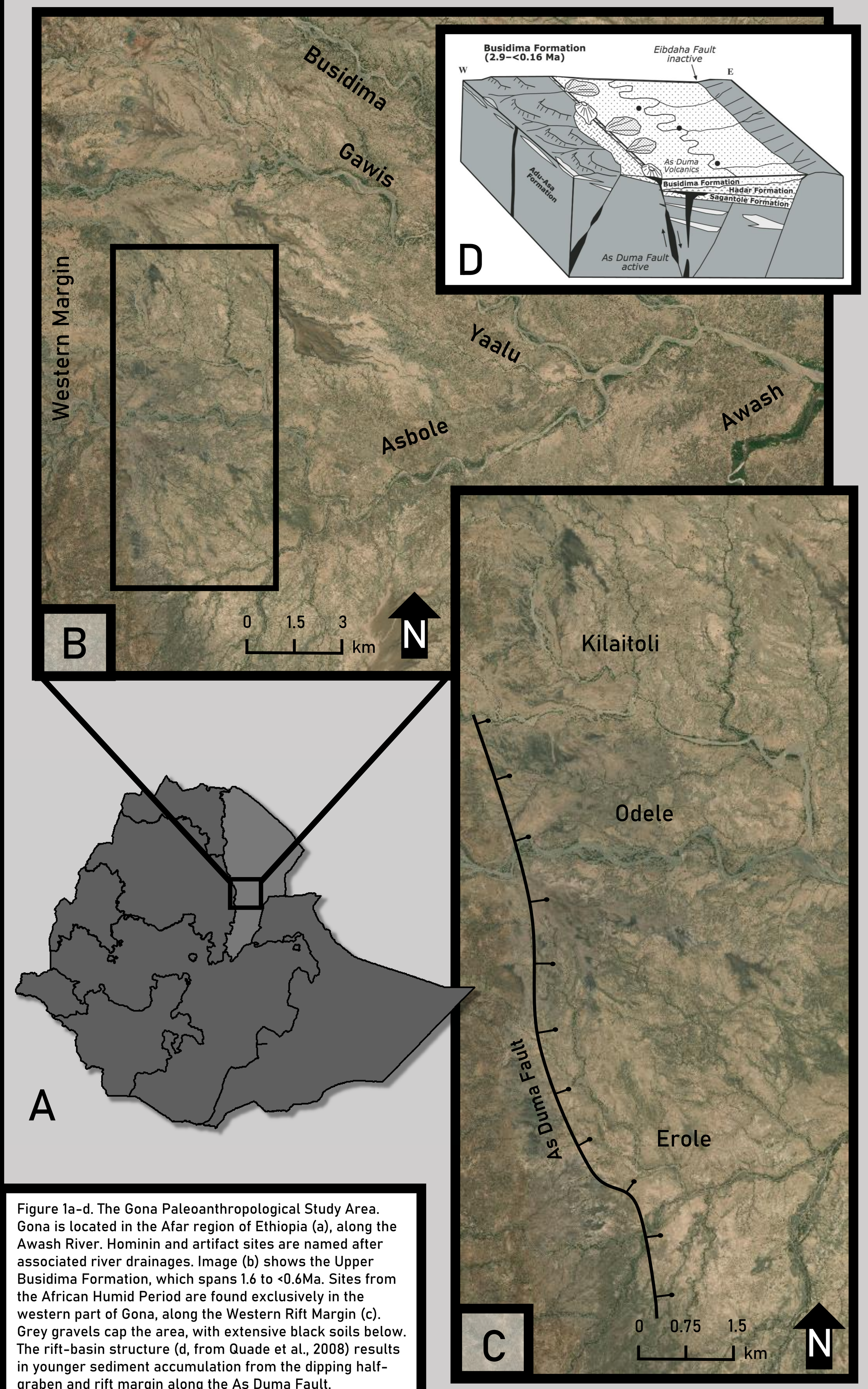

Figure 1a-d. The Gona Paleoanthropological Study Area. Gona is located in the Afar region of Ethiopia (a), along the Awash River. Hominin and artifact sites are named after associated river drainages. Image (b) shows the Upper Busidima Formation, which spans 1.6 to <0.6Ma. Sites from the African Humid Period are found exclusively in the western part of Gona, along the Western Rift Margin (c). Grey gravels cap the area, with extensive black soils below. The rift-basin structure (d, from Quade et al., 2008) results in younger sediment accumulation from the dipping half-graben and rift margin along the As Duma Fault.

Stratigraphy and Geochronology

- Dates obtained from tephra establish the two paleosols as from the younger than 25ka and from the Last Glacial Period (Fig. 4a)
  - Radiocarbon dates from gastropods yield ages of ~12ka, within the duration of the AHP
- The AHP soil (Fig. 4b) may be the Halalalee Bed, which marks the top of the Busidima Formation
- The paleosol from Odele (Fig. 4c) weathered during the LGP, a drier time interval than the AHP
- Differences in soil features (color, physical structure, pH, EC) may be due to differences in climate, flora, and fauna
  - Both soils formed on tributary floodplains

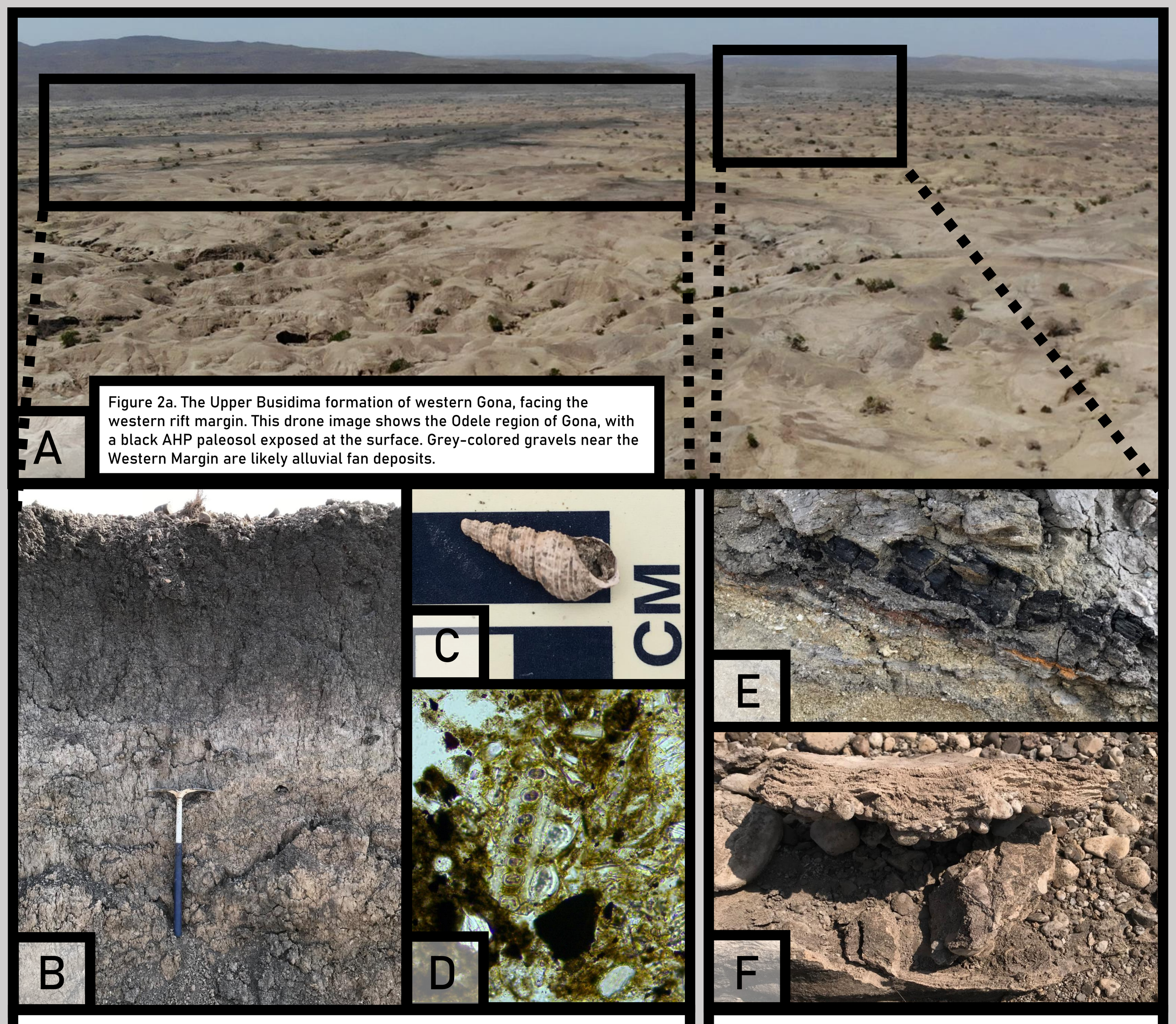

Figure 2a. The Upper Busidima formation of western Gona, facing the western rift margin. This drone image shows the Odele region of Gona, with a black AHP paleosol exposed at the surface. Grey-colored gravels near the Western Margin are likely alluvial fan deposits.

Figure 2b-d. The AHP paleosol. A dark soil at Erole (b) indicates high amounts of organic matter with aquatic gastropod *Melanoides* sp. (c) in the grey later, suggesting perennial water. *In-situ* bilobate phytoliths (d) originate from a grass.

Figure 2e&f. Other environmental indicators. Carbonized wood (e) suggest enough available water to support the growth of gallery forests, perhaps from springs, as indicated by tufa (f).

Sedimentology

- AHP soils and sediments (Fig. 2b) occur in the westernmost parts of Gona, flanking the western rift margin (Fig. 1c,d)
  - Widespread along the Odele, Erole, and Kilaitoli drainages
- Inverted channels (Fig. 2a) and tufa (Fig. 2f) suggest channels and distal springs characteristic of an alluvial fan environment
- Aquatic freshwater gastropods such as *Melanoides* sp. (Fig. 2c), *Bellamya* sp., and *Planorbidae* indicate perennial water in the area
  - Likely inhabited freshwater springs and ponded areas within the alluvial fan
- Direct evidence for grasses (Fig. 2d) and larger woody plants (Fig. 2e) such as trees
- Organic-rich black mat deposits at Odele (Fig. 3, see dashed lines) with abundant *Melanoides* sp. are representative of spring-fed wetlands (Quade et al., 1998)

Figure 3. Black mat deposits at Odele. A profile associated with AHP deposits at Odele (ODE18-02) contains multiple layers of potential "black mats", organic-rich deposits common in the Southwestern United States dating to the Pleistocene-Holocene boundary. They are associated with an abundance of aquatic gastropods such as *Melanoides* sp. and *Bellamya* sp.

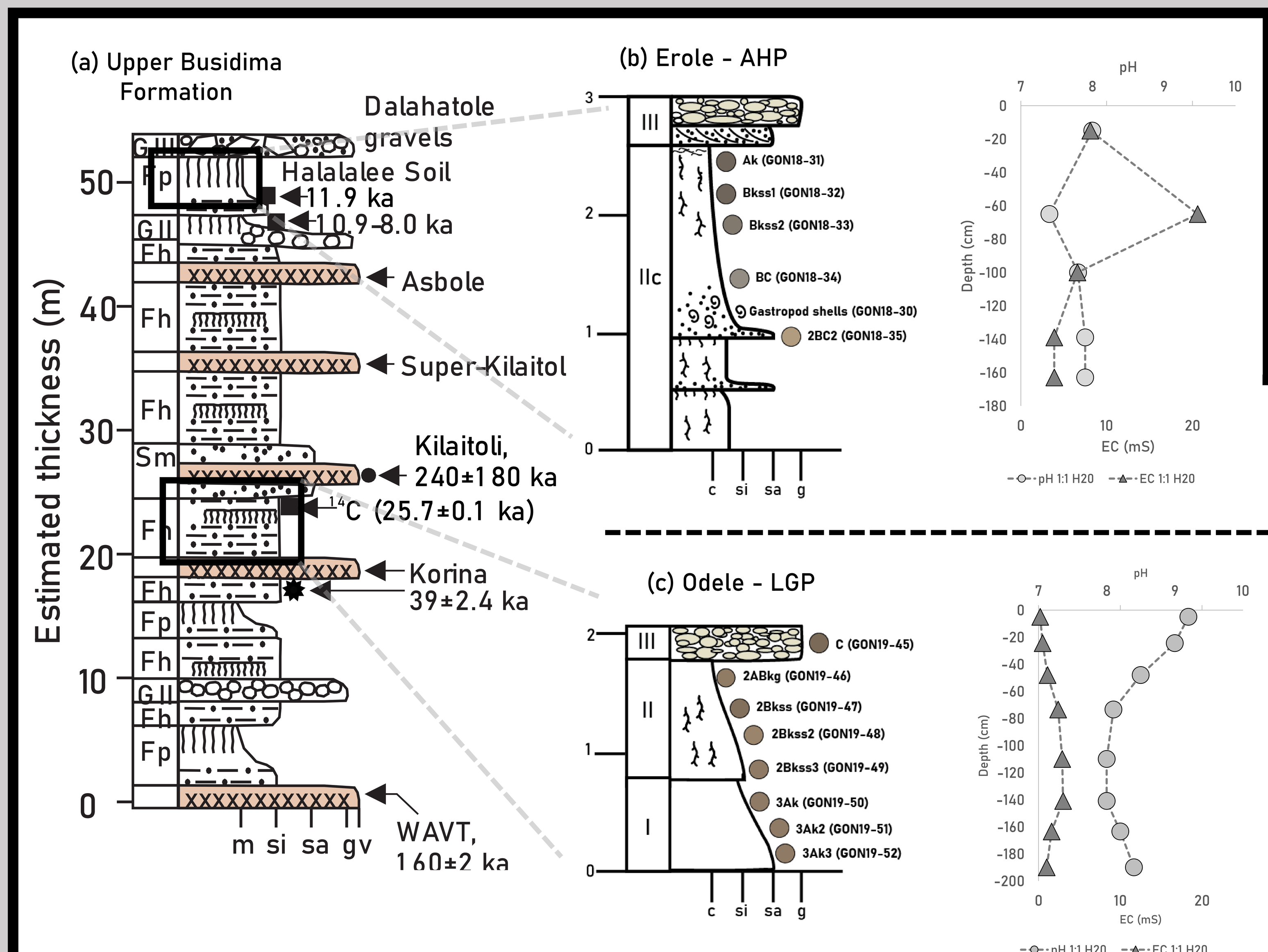

Figure 4a-c. Geochronology and paleosol characteristics. Radiocarbon dates and tephra ages in the Upper Busidima Formation (a) provide a good temporal framework for paleosols sampled. The AHP paleosol at Erole (b) is younger than 11.9ka and weathered during the AHP. Darker soil color suggests higher amounts of organic matter. The LGP paleosol at Odele (c) is consistently lighter. Both paleosols have consistently alkaline pH values and similar EC values.

Geochemistry

- Geochemical calculations use properties from the paleosol's parent material and concentrations of immobile elements such as Ti or Zr
- Strain (Fig. 5a) measures volumetric change in a soil
  - Greater collapse during the AHP indicates more weathering via rainfall, shrink/swell, and bioturbation
- Tau (Fig. 5b) measures elemental gain or loss in a soil
  - Greater loss of Si and Ca in the AHP suggests more water infiltration and leaching

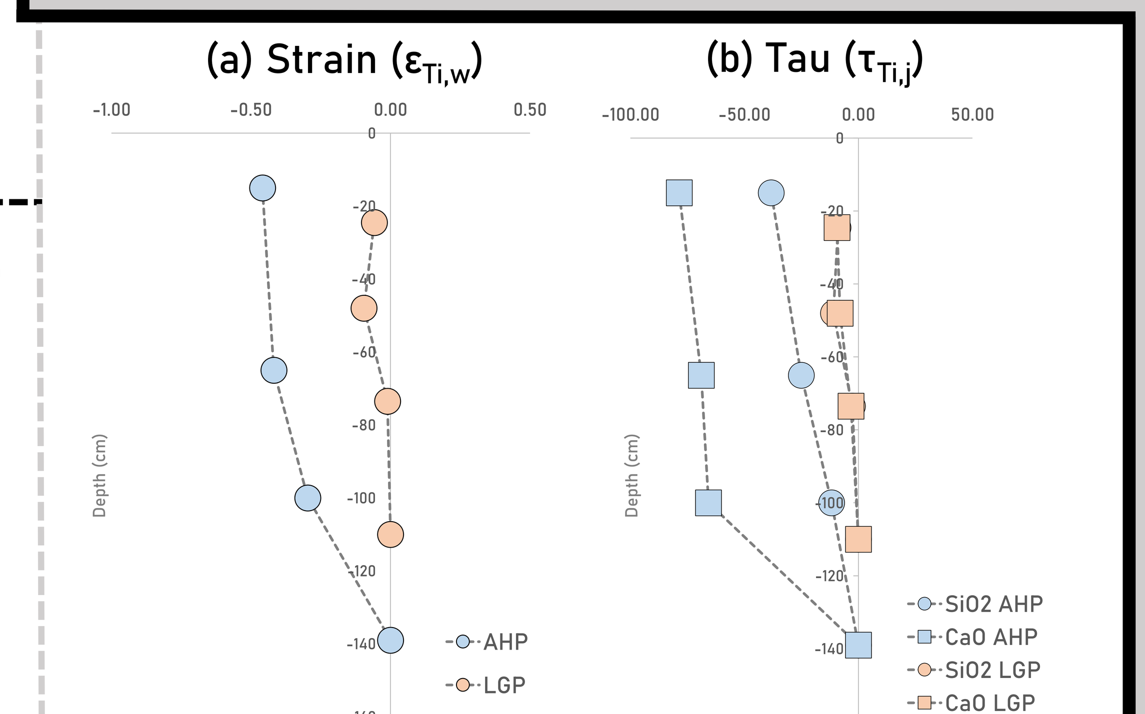

Figure 5a&b. Geochemistry of paleosols. Strain (a) values are consistently lower at Erole (-39 ± 8 %) than at Odele (-5 ± 4 %). Tau (b) values at Erole are also consistently lower (25 ± 13 % SiO_2 and 71 ± 6 % CaO) than at Odele (8 ± 4 % SiO_2 and 7 ± 3 % CaO), suggesting more rainfall and weathering during the AHP.

Discussion

- Sedimentological and geomorphic features suggest ponded environments along an alluvial fan during the AHP (Fig. 2a,f)
- Abundance of aquatic gastropods and evidence of increased vegetation (Fig. 2b,c,d,e)
- Evidence of dynamic, shifting landscapes during the AHP (Fig. 3)
- Geochronology and analysis of paleosols (Fig. 4a-c) show differences in soil properties despite the same depositional environment
- Geochemical calculations (Fig. 5a,b) yield volumetric collapse and elemental loss for the AHP soil
  - Lower strain during the AHP due to greater weathering, bioturbation, shrink/swell
  - Si and Ca loss from increased amounts of water draining through the soil during the AHP, likely due to increased rainfall and ponding environments (Sommer et al., 2006)

Conclusion

- The African Humid Period is present in sedimentary deposits at Gona, Ethiopia
- Sites studied suggest an increase in rainfall and are part of an alluvial fan environment
  - Results in stream channels, springs, and spring-fed wetlands
- More hospitable to *Homo sapiens* in the area
  - Relative abundance of natural resources in the AHP compared to the LGP
  - More available water
- Studying the AHP allows us to understand human-environment interactions in a time of fluctuating climate patterns
- Work is ongoing to study the black mats and associated deposits

Acknowledgements and References

The authors would like to thank Michael Rogers, Sileshi Semaw, Jay Quade, Naomi Levin, Nelia Dunbar, William McIntosh, Nels Iverson, Lee Arnold, and Mathieu Duval for their collaborative efforts as well as the Afar People, the National Museums of Ethiopia, and the ARCCH. We would also like to thank the National Geographic Society (Grant EC-52923R-18), the Watershed Studies Institute, the Geological Society of America, the Murray State University Office of Research and Creative Activity, and the Murray State University Department of Earth and Environmental Sciences for funding and support.

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