Enamel Proxies for Paleoclimate at 3.97 Ma Allia Bay, northern Kenya

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Environment and Bipedalism

- Savanna Hypothesis
- Forest Hypothesis
- Shifting Heterogeneity Model
Millions of Years Ago

Human ancestors and relatives
(courtesy Bernard Wood, 2009)

(H. habilis)

H. erectus

H. ergaster *

H. rudolfensis *

H. habilis

P. aethiopicus *

P. robustus

P. boisei

H. sapiens

H. neanderthalensis

H. antecessor *

H. floresiensis

H. heidelbergensis

K. platyops *

Au. bahrelghazali *

Au. garhi *

Au. afarensis

Au. africanus *

Ar. ramidus *

Ar. kadabba *

O. tugenensis *

S. tchadensis *

Australopithecus anamensis *

(Wood and Lonegran 2008)
Australopithecus anamensis

Earliest confirmed biped: ankle and knee

(Feibel 2011)
Allia Bay: Area 261-1

Ancient Omo River: Channel and floodplain

(Feibel 2011)
Allia Bay Region: 1 short rainy season (from Cerling et al. 2010)
Allia Bay Region: 1 short rainy season (from Cerling et al. 2010)

Nairobi, 2 rainy seasons w/closed forests
Tooth enamel as Paleoclimate Proxy

Deer from wet areas and dry areas

Data from Luz et al., 1990

\( \delta^{18}O_{\text{bone phosphate}} \%e \text{ SMOW} \)

\( \delta^{18}O_{\text{local rain}} \%e \text{ SMOW, annual average} \)
Obligate Drinkers

- Enamel $\delta^{18}O$ reflects meteoric water $\delta^{18}O$
  - $\delta^{18}O_{en}$ correlates with composition of precipitation ($\delta^{18}O_{ppt}$)

- Meteoric water $\delta^{18}O$ varies as a factor of altitude, temperature, distance from the sea, and mean annual precipitation

Equids
Elephants
Hippos
Non-obligate Drinkers

- **Enamel $\delta^{18}O$ reflects leaf water $\delta^{18}O$**

- **Leaf water $\delta^{18}O$ factor of relative humidity due to evaporative enrichment**

- **Increased aridity, the greater the evaporation rate and results in increased $\delta^{18}O$**

(Woodward 2008)
High aridity = high $\delta^{18}O$

$\delta^{18}O$ value in rain is temperature dependent
Cold = low $\delta^{18}O$

Gazelle
Drought Tolerant

Goat
Obligate Drinker

(Hallin, Schoeninger, Schwarcz 2012 JHE)
Seasonal variation in $\delta^{18}O$ values recorded in modern dental enamel (Kohn et al. 1998)
From:
(Kohn et al. 1998)
Turkana Basin Source Water

The Omo River (originates in the Ethiopian Highlands)

Allia Bay
**Allia Bay Fossil Samples (n=24)**

- **δ^18O (non-drinker)**
  - Giraffe, n=2
  - Bovids, n=3
  - Only enamel fragments.
  - Limited to what is available.

- **δ^18O (drinkers)**
  - Rhino, n=1
  - Elephants, n=4
  - Hippo, n=9
  - Suids, n=5
Perikymata & Striae of Retzius
Spot Sample Analysis

(Hippo)
Tooth Thin Sections

Altered/Unaltered Boundary

Alteration

Cathodoluminescence (CL) Image (Schoeninger et al. 2003)
Expectation: The $\delta^{18}$O values represent the paleoenvironment shifts in rainfall during enamel development.

H₀: No change in $\delta^{18}$O values corresponding to the altered/unaltered boundary detected by CL.
**H₀:** No change in $\delta^{18}O$ values corresponding to the altered/unaltered boundary detected by CL.

**Expectation:** The source of $\delta^{18}O$ is constant throughout the year and water always available or altered rapidly.
H1: The curve of $\delta^{18}O$ values corresponds to the altered/unaltered boundary detected by CL.

Expectation: Only the $\delta^{18}O$ values in the unaltered region of enamel represent the paleoenvironment shifts in rainfall.
Lake Turkana

Hot/dry environment with 1 rainy season and little seasonality

(Kohn et al. 1998)
Nairobi
Cooler/wetter environment with 2 rainy seasons and marked seasonality

(Kohn et al. 1998)
Conclusion

• 1 rainy season
  – Support open savanna hypothesis

• 2 rainy seasons
  – Support closed forest/mixed habitat hypotheses

• Environment that supported a group of early bipedal hominins