Title: Modelling hominin dispersal to southern Africa through evolving landscape and climate resistance surfaces

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Early hominin presence in temperate southern Africa during the Pliocene, millions of years before the Pleistocene Out-of-Africa dispersal of modern humans, raises a fundamental question: what drove (or underlies) this early pan-African distribution? Despite growing interest in hominin paleobiogeography, the landscape and environmental mechanisms governing hominin distribution and potential dispersal corridors between eastern and southern Africa remain poorly understood and constrained. Thus far, dispersal models rely predominantly on topographic cost surfaces, neglecting the dynamic interplay between drainage network evolution, paleoclimate, and vegetation change that characterised the Plio-Pleistocene.

The ERC-funded PLIODIS project addresses this gap by reconstructing the coupled geomorphological and paleoenvironmental evolution of the Kalahari/proto-Limpopo basin and the Zambezian region, aiming to integrate these reconstructions into a dynamic dispersal modelling framework. We build a time-evolving resistance surface that combines topography, drainage network geometry, and environmental layers. Least-Cost Path (LCP) analysis and Markovian stochastic walks are then applied to the same evolving surface, contrasting deterministic optimal corridors with probabilistic movement outcomes.

Here we present pilot results combining geomorphological changes (topography and river network reorganisation) with climatic and environmental resistance layers to model hominin dispersal pathways toward southern Africa. Applying both LCP and Markovian approaches to the same dynamic surface reveals how sensitive inferred corridors are to landscape and climate change, and at what times and along which routes dispersal to southern Africa was most plausible.

This approach lays the foundation to provide a quantitative method for evaluating when dispersal corridors opened or closed during the Plio-Pleistocene, and for contextualising the hominin fossil record of southern Africa within an explicitly dynamic landscape framework.

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PLIODIS
Plio-Pleistocene Dispersal

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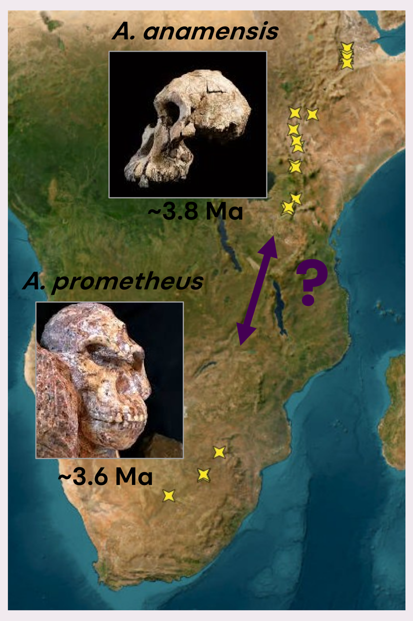
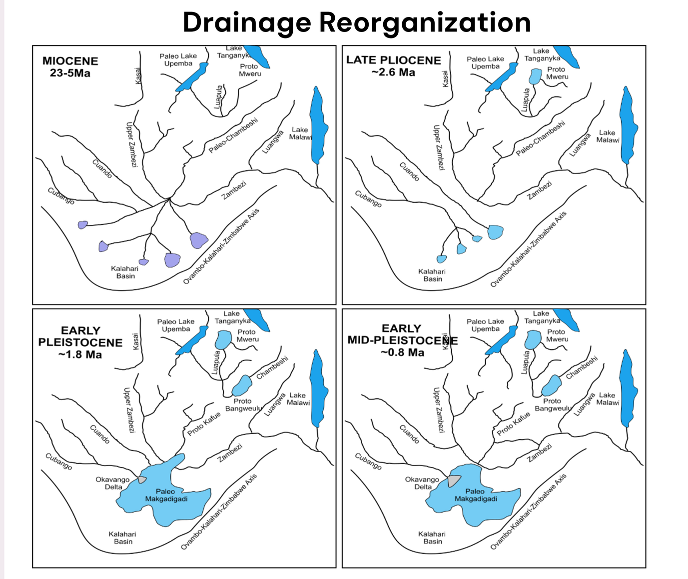
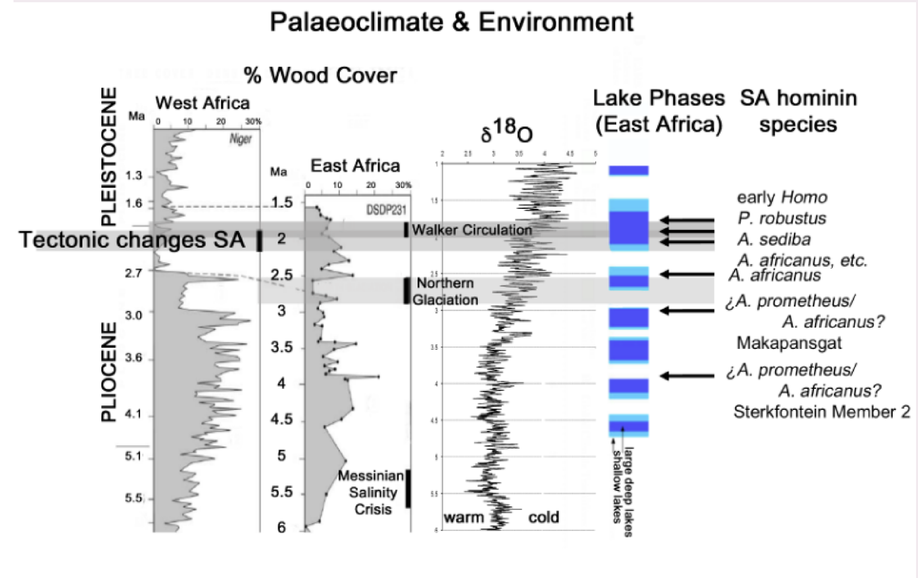
Pliocene Hominin Dispersal to southern Africa: Choice or Chance?



Early hominin sites are known from eastern and southern Africa, with vast intervening regions where no fossils have yet been found. Despite this apparent gap, hominins from eastern and southern Africa are believed to be closely related. This raises important questions: what was the pan-African distribution of early hominins? Were these regions connected in the past?

As part of the ERC-funded PLIODIS project, we investigate landscape changes during the Plio-Pleistocene and explore potential migration routes.

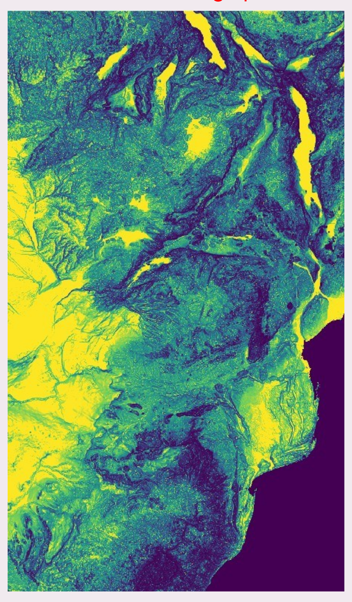




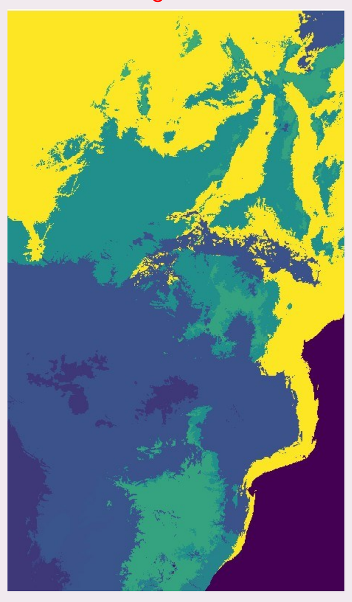
Modelling hominin dispersal

Least Cost Path analyses are based on the "Principle of Least Effort" (Zipf 1949), which assumes that humans tend to choose routes of least resistance when moving through a landscape. Various factors influence this choice, including surface ruggedness, climate, and the availability of food and water.

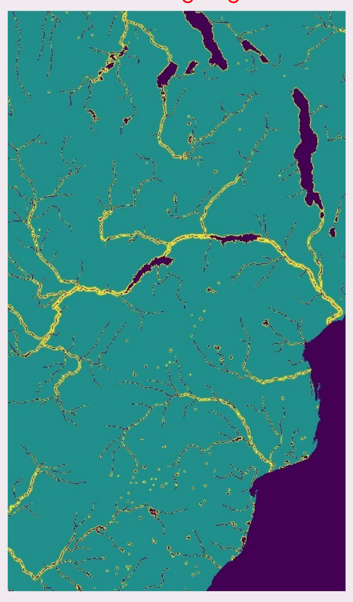
Topographical cost
Slope dependent
Cost of climbing uphill



Environmental cost
Köppen classification
Cost of moving in harsh climate



River Network cost (& attractiveness)
Strahler Order
Cost of crossing large rivers

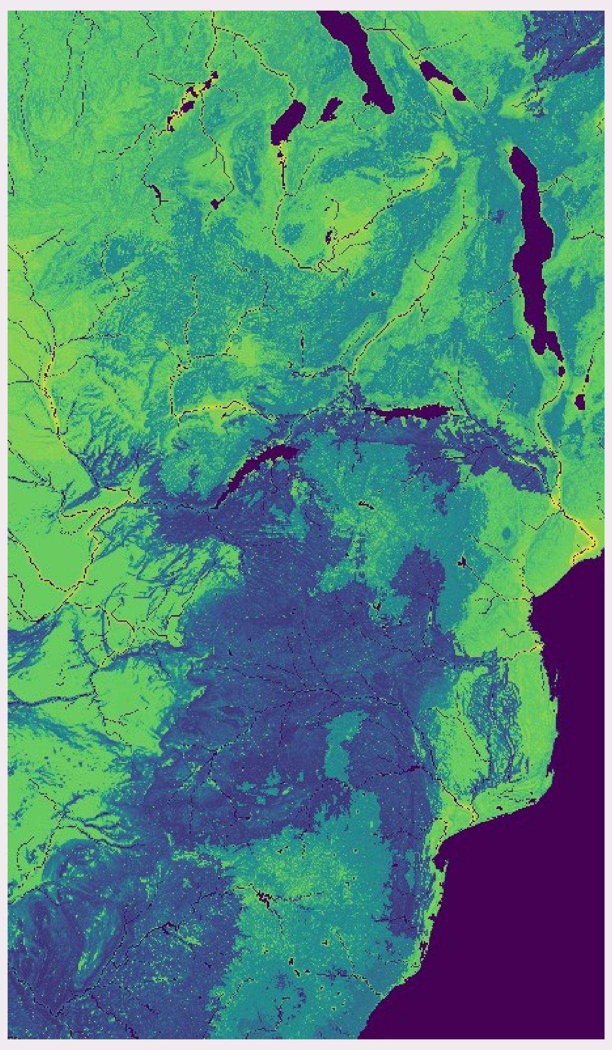


Each cost map is resampled and normalized

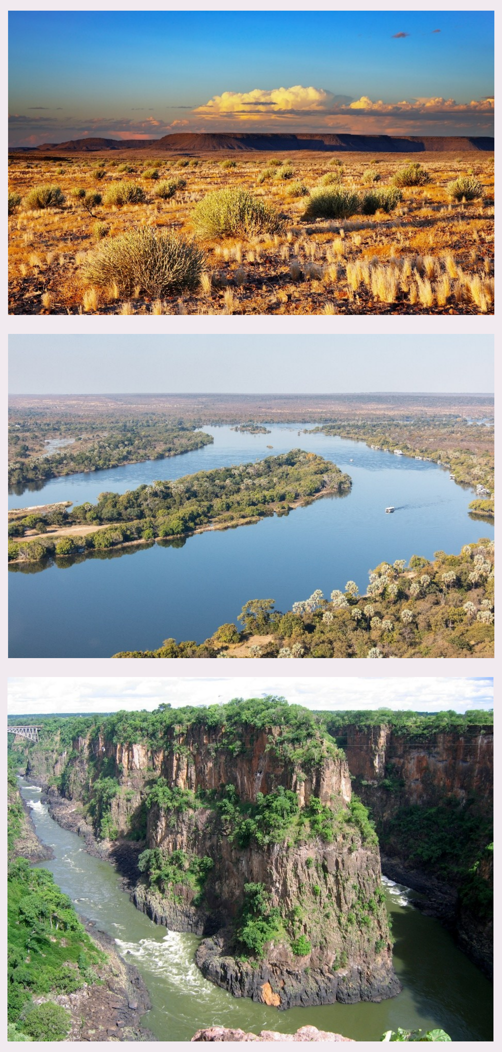
The total cost surface is computed as a weighted linear combination:

$$\boxed{c_{\mathrm{total}}(i) = w_{\mathrm{topo}} \cdot c_{\mathrm{topo}}(i) + w_{\mathrm{river}} \cdot c_{\mathrm{river}}(i) + w_{\mathrm{env}} \cdot c_{\mathrm{env}}(i)}$$

Combined total cost



African landscapes



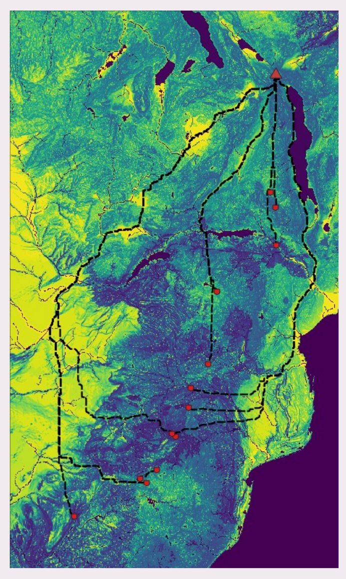
Increasing cost of movement

Would you rather follow a river, try cross it or walk in the savanna?

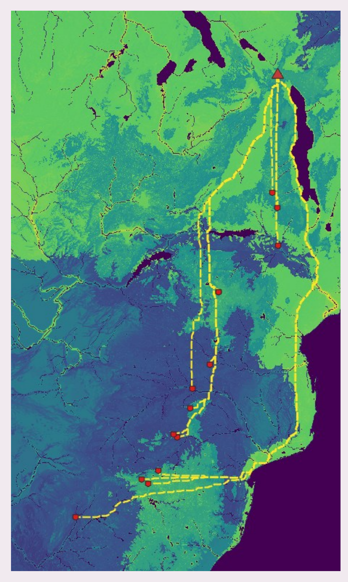
Least Cost Path requires an origin and a destination point. The origin is set between lake Malawi and lake Tanganyika, a probable passage point for southward dispersal. The destination is *Makapansgat*, a cave site with various fossil bones of australophitecus, connected by a series of intermediate points.

LCP are affected by climate?

A skewed cost toward topography or environmental surfaces modifies potential paths. Arid conditions in the continental interioe favour a costal path.



$w_{\mathrm{topo}} = 3 \quad w_{\mathrm{env}} = 1$

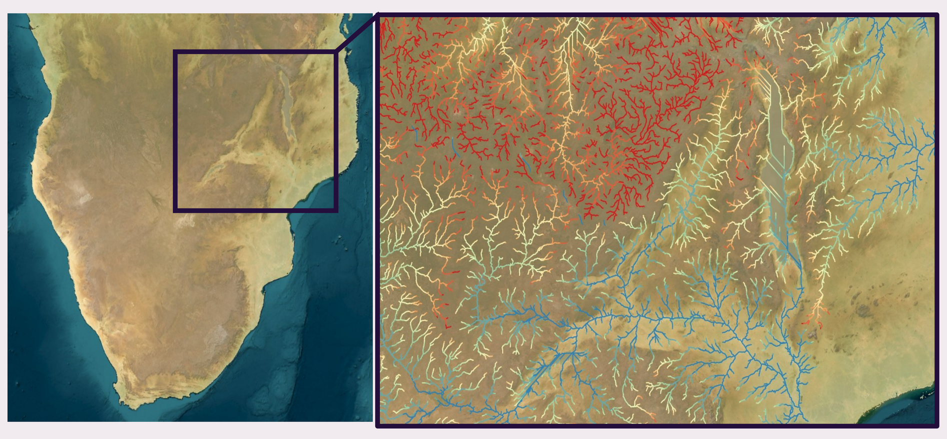


$w_{\mathrm{topo}} = 1 \quad w_{\mathrm{env}} = 3$

A landscape evolution modelling approach for drainage capture

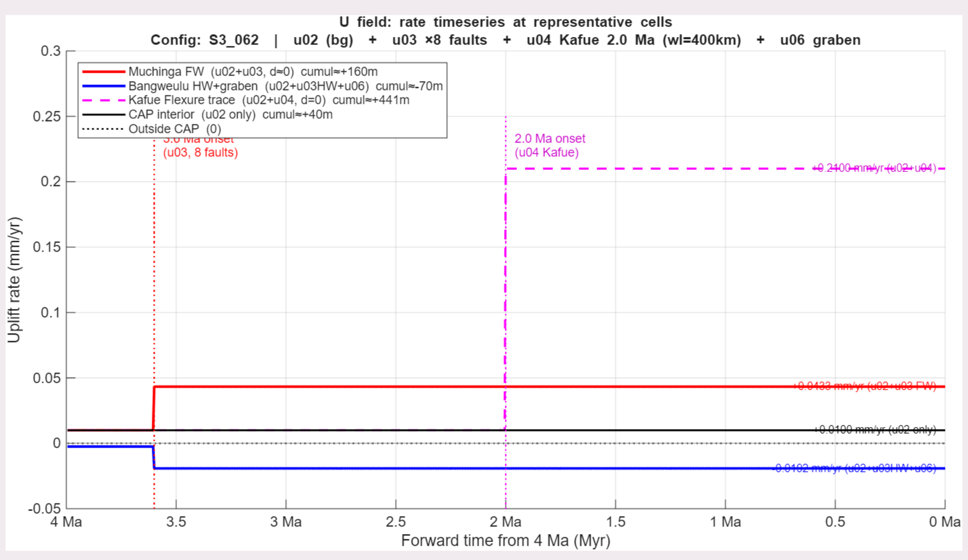
We use the TopoToolbox (Schwanghart et al., 2010) Landscape Evolution Model (TTLEM), which solves the stream-power incision law $E = K \cdot A^m \cdot S^n$ (E is erosion [m/yr], K is erodibility coefficient [m$^{(1-2m)}$/yr], A is upstream drainage area [m²], m is the area exponent and n is the slope exponent) on a fixed grid under prescribed, time-varying uplift.

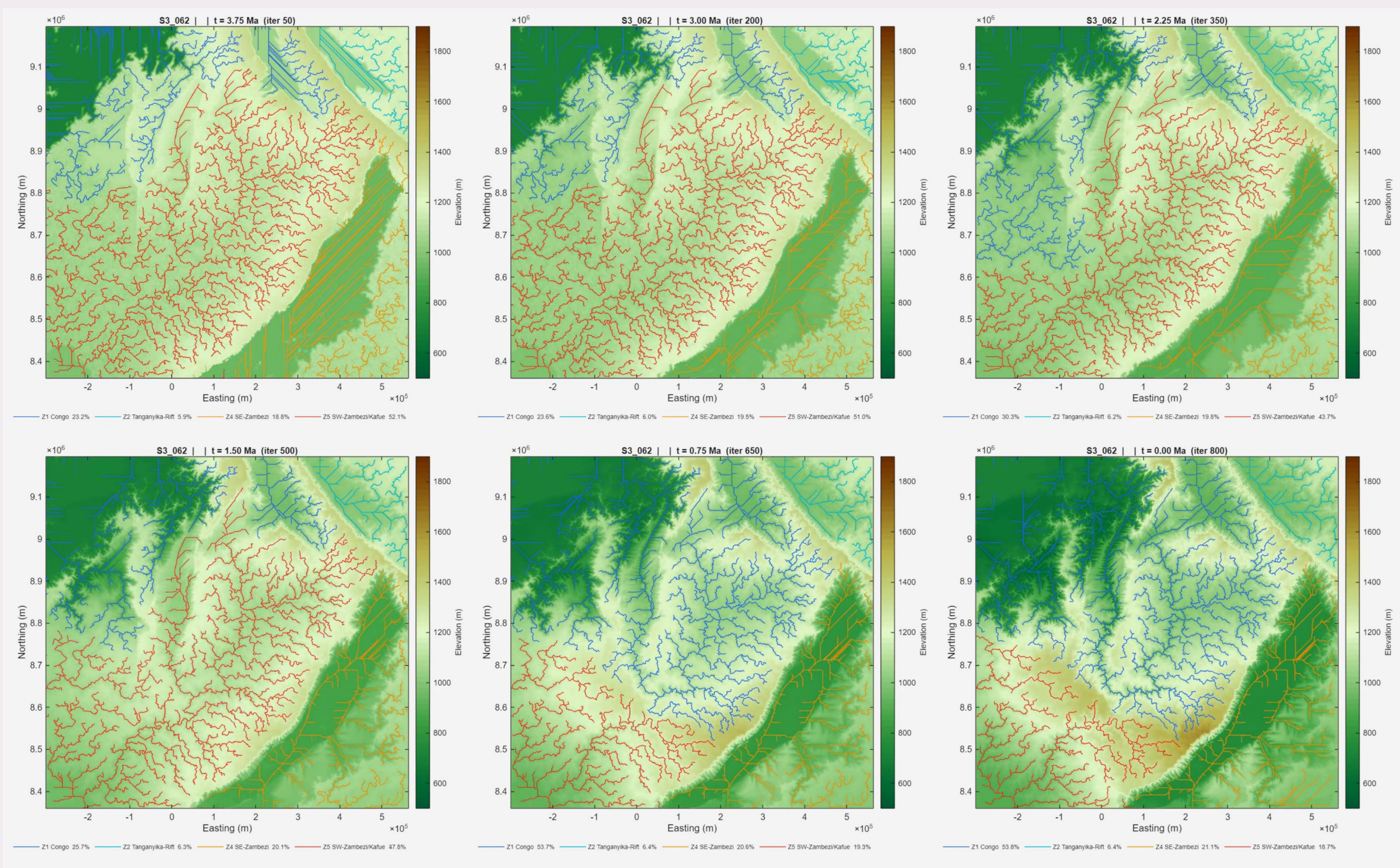
Study Area: Central African Plateau (CAP)



X-values suggest that CAP uplift may have reorganized the course of the Chambeshi – Kafue drainage during the Plio-Pleistocene.

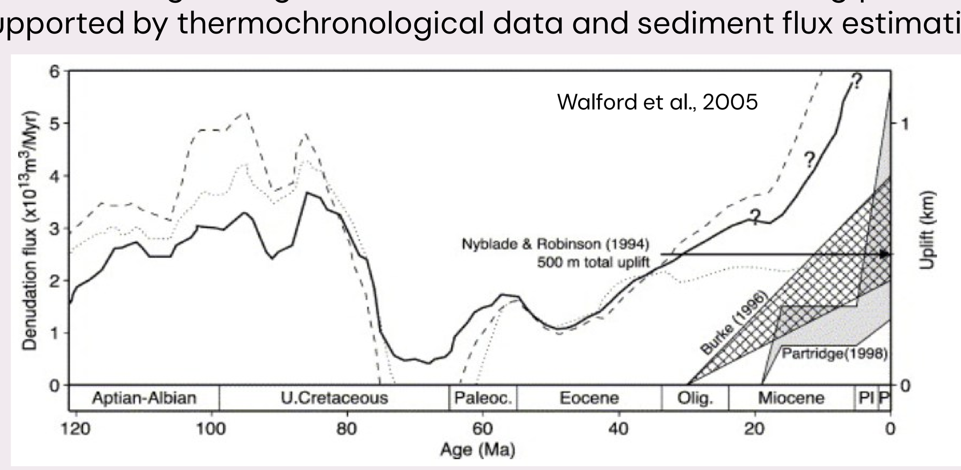
Partitioned uplift





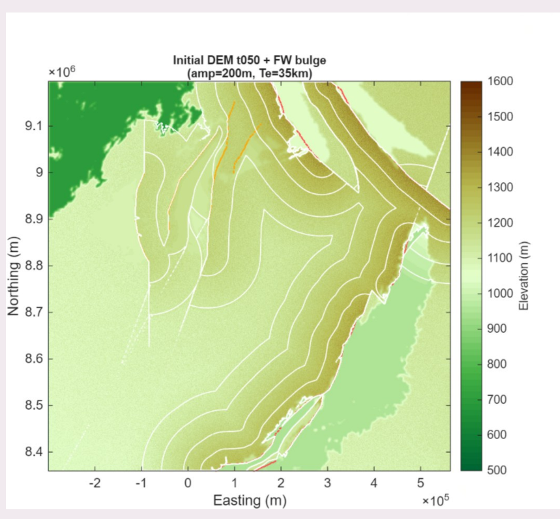
How to test the model?

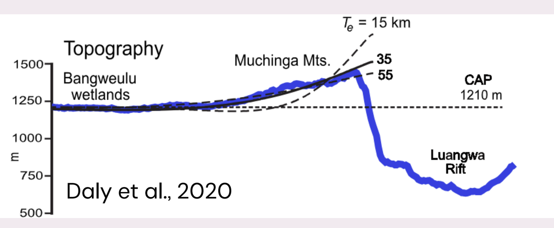
To test the model, drainage reorganization can be reconstructed using provenance studies in river deltas, supported by thermochronological data and sediment flux estimation.



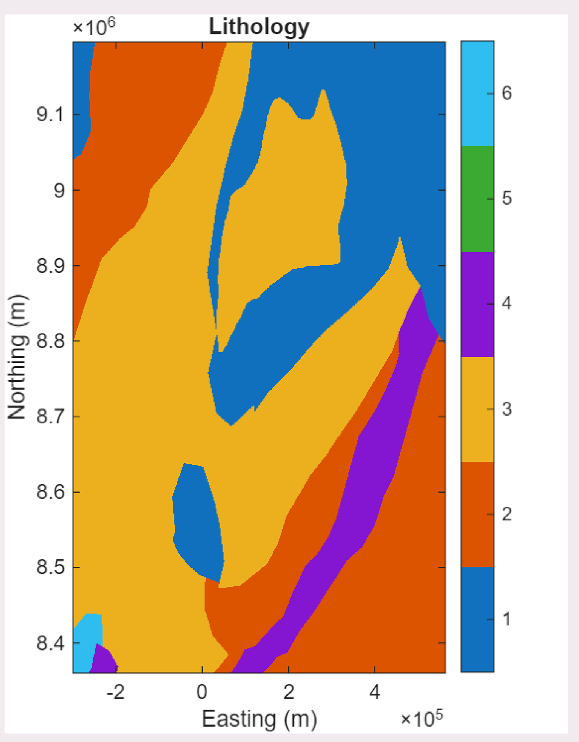
LCP suggests that the river network plays a dual role in hominin dispersal: creating corridors along the trunk while acting as a barrier when crossing is required. A connected Kafue–Chambeshi drainage up to ~1.5 Ma may have played a major role in directing hominins southward.

Pre-existing faults control

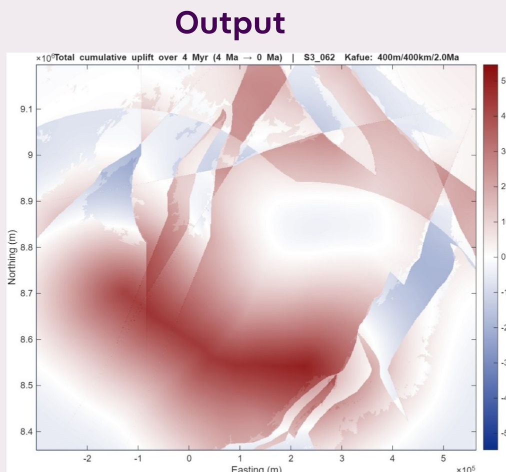


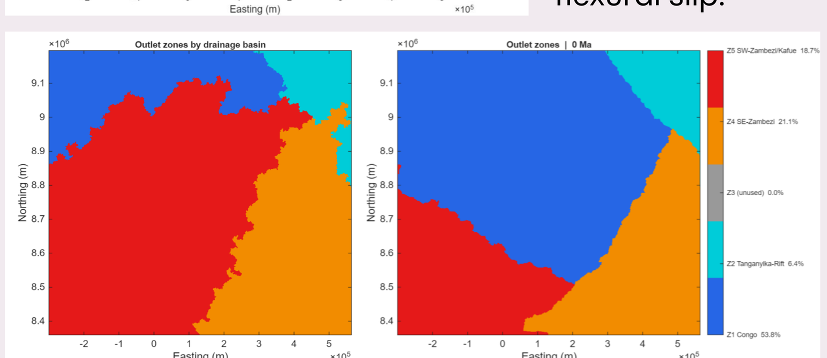


Erodibility



Output





Preliminary results suggest that the Kafue–Chambeshi disruption can only be explained by a complex interplay of headward erosion, subsidence, and flexural slip.

If you are interested in the project visit PLIODIS website: pliodis.github.io

ARCHAEOLOGY, ENVIRONMENTAL CHANGES & GEO-CHEMISTRY RESEARCH GROUP

"Little Foot" (Stw 573)– Sterkfontein

"Not all who wander are lost"

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