The Environmental Dynamics of Human Evolution

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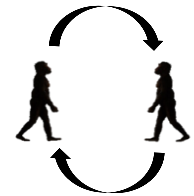
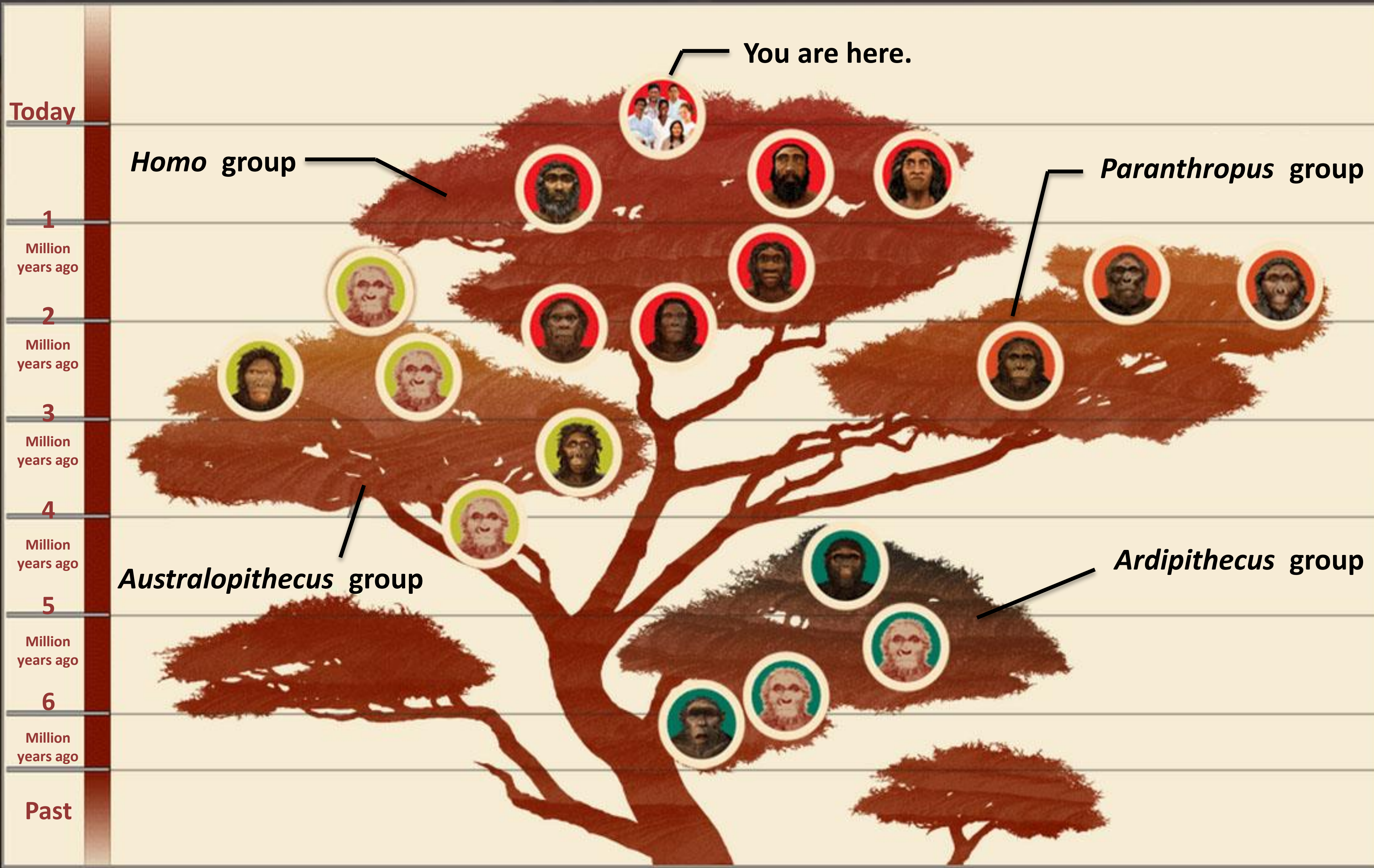
Evidence of the accumulation of human qualities

TIME	EVOLUTIONARY CHANGE	
100 ka to present	Increased cultural diversity & technological innovation	
by 250 ka	Enhanced symbolic behavior	
by 250 ka	Complex spatial mapping & resource exchange	
by 800 - 400 ka	Controlling fire & building shelters	
800 - 200 ka	Most rapid increase in relative brain size	
by 1.7 Ma	Initial advances in stone technology	
by 2.0 – 1.5 Ma	Pronounced elongation of the legs	
by 2.0 Ma	Extensive carrying of stones & food	
by 2.6 Ma	Simple stone flaking	
by 4 – 3 Ma	Increased range of foods eaten	
~6 – 2 Ma	Bipedal walking & tree climbing	

ka = thousands of years ago

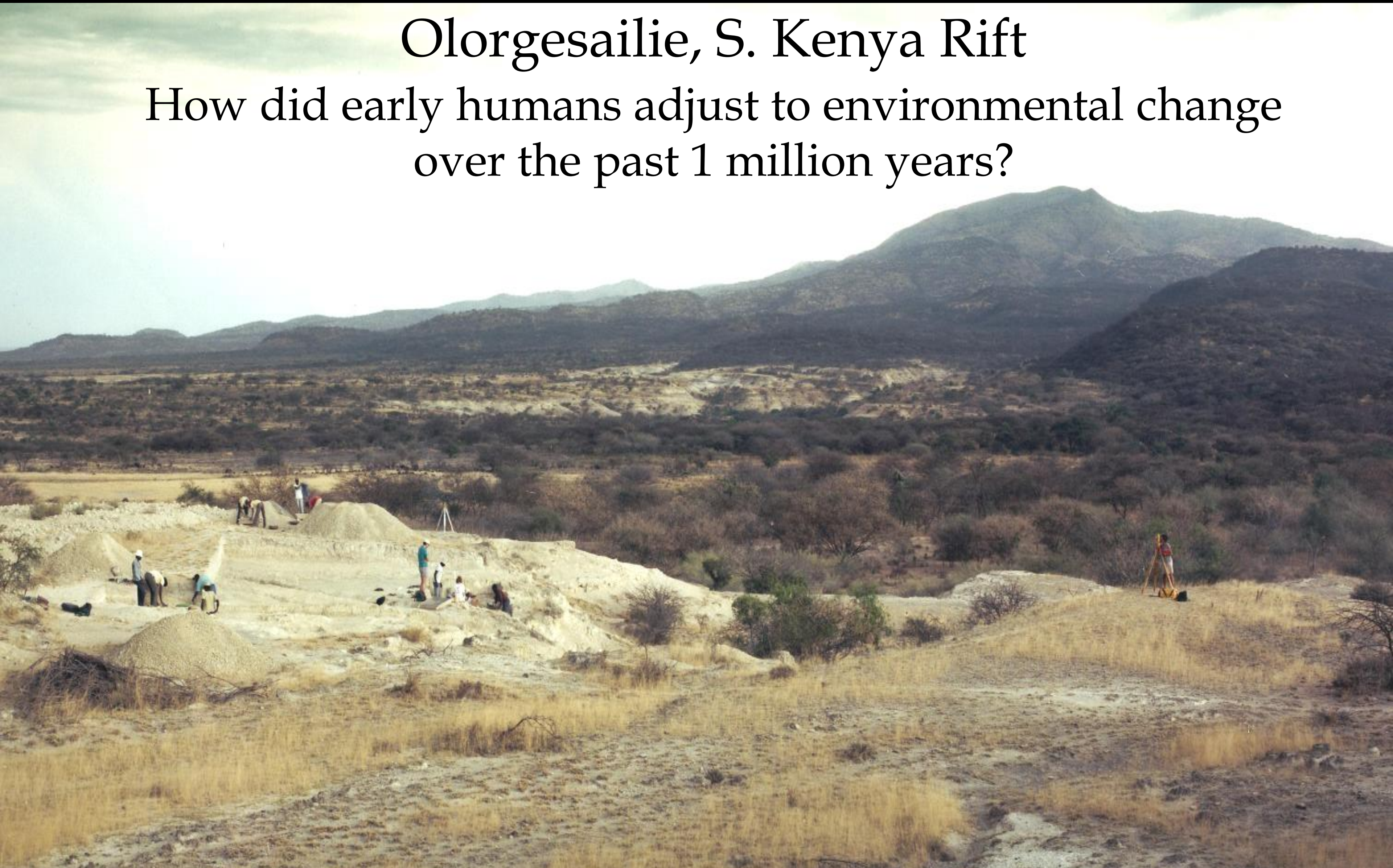
Ma = millions of years ago



You are here.
Today
Homo group
Paranthropus group
1
Million years ago
2
Million years ago
3
Million years ago
4
Million years ago
Australopithecus group
Ardipithecus group
5
Million years ago
6
Million years ago
Past

Olorgesailie, S. Kenya Rift

How did early humans adjust to environmental change over the past 1 million years?



Overview of the talk

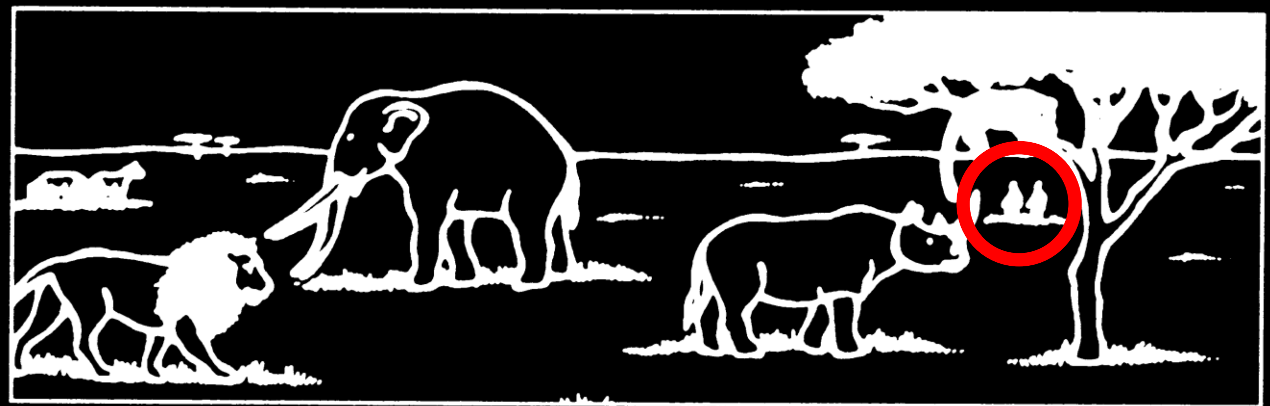
1. Background to why environmental variability provides the critical context for human evolution

2. Alternating phases of high/low climate variability: A new framework for tropical/subtropical African climate

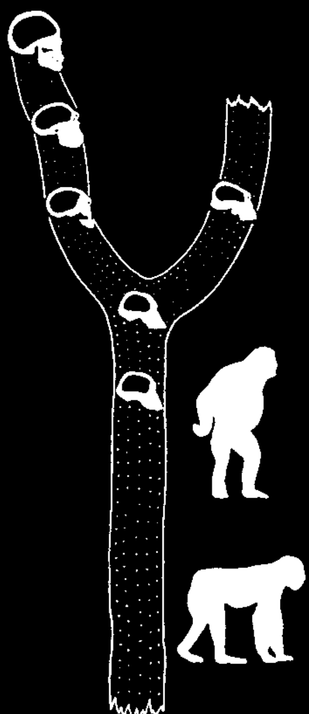
3. Can adaptability evolve?

4. African climate variability linked to the origin of *Homo sapiens*

Potential evolutionary responses to environmental change



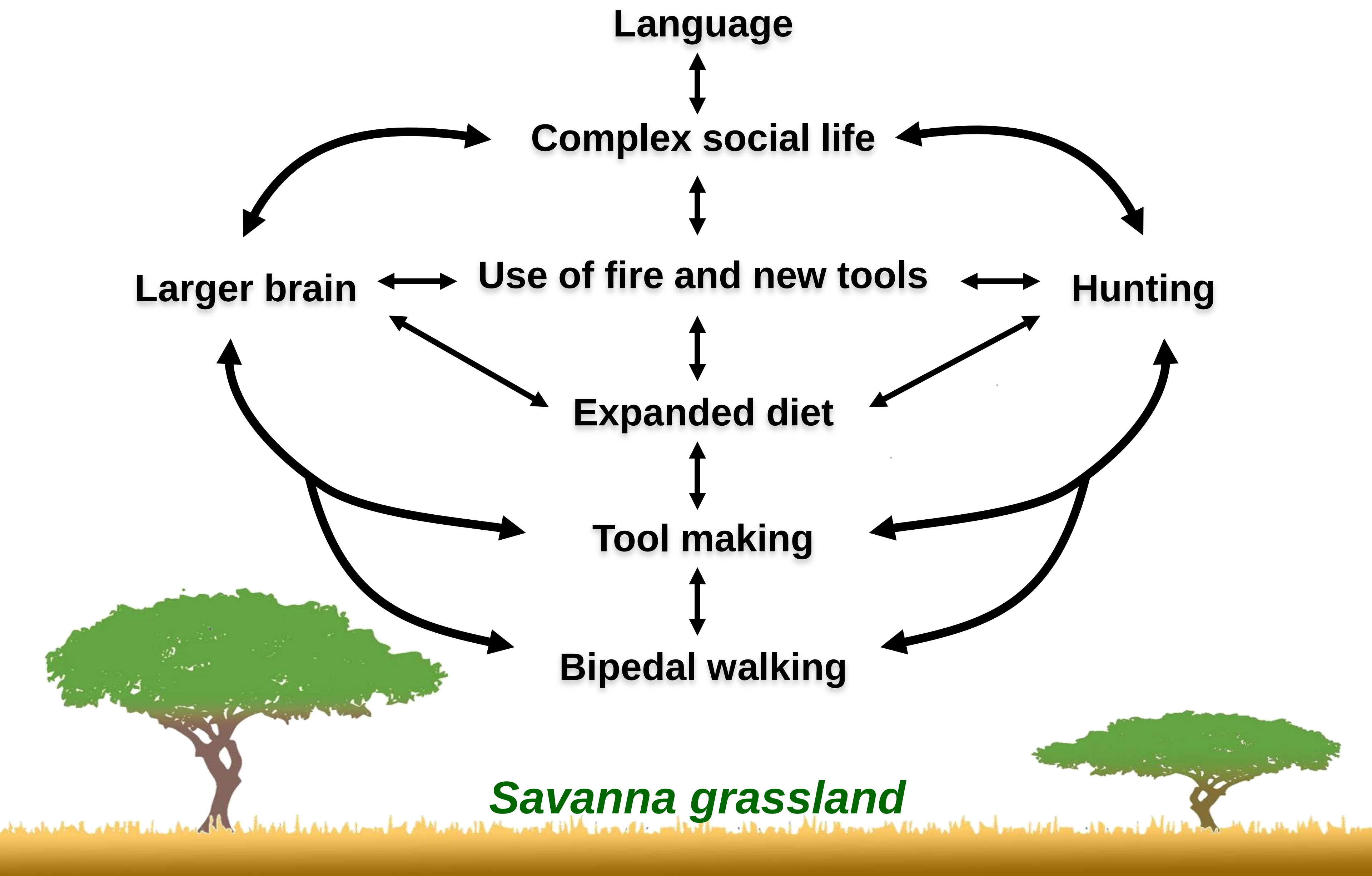
Onset & spread of novel behaviors & ecological interactions



Morphological change, speciation, extinction

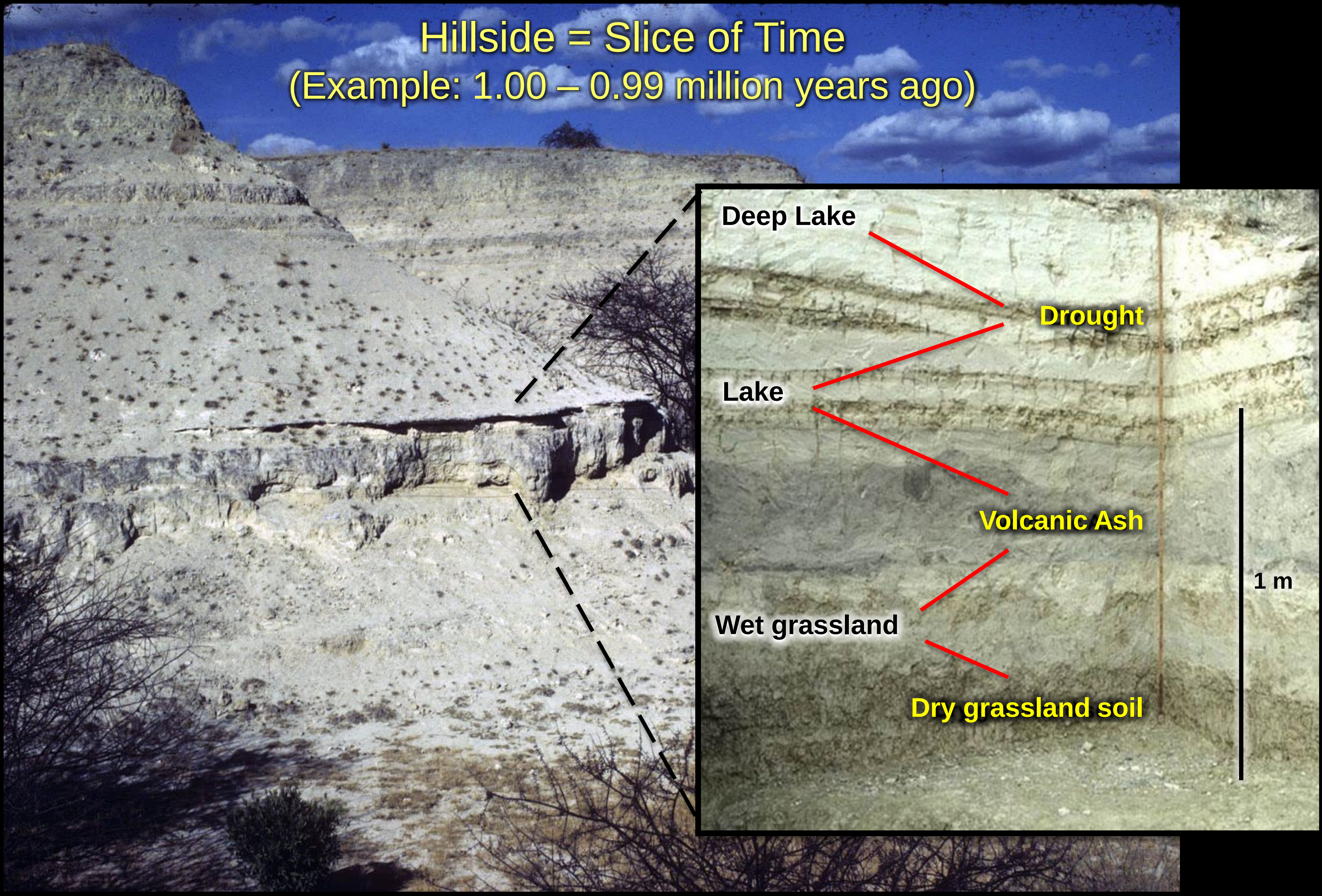
Olorgesailie: Rift Valley, southern Kenya

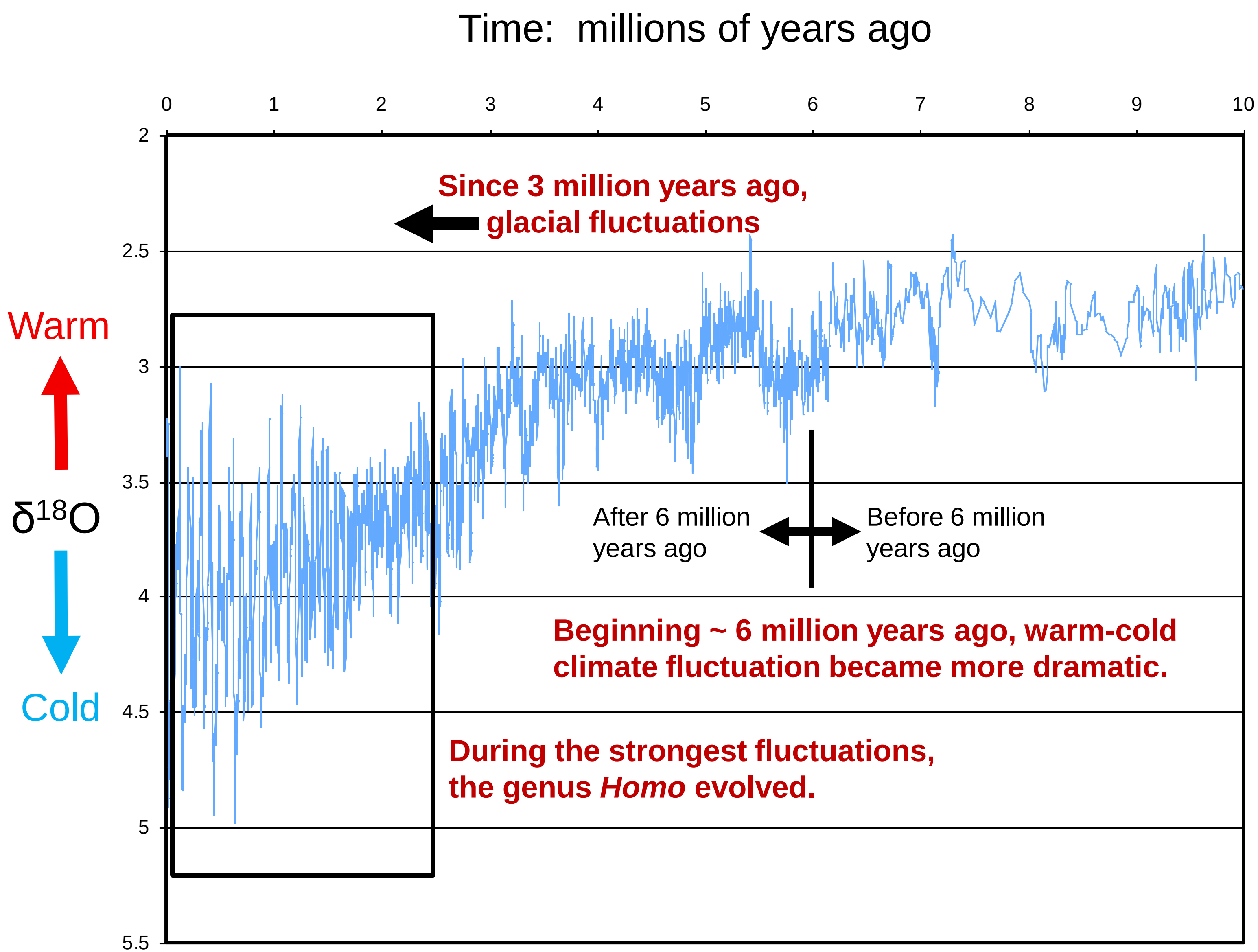
Savanna Hypothesis of Human Evolution



Olorgesailie
~ 670,000 to 633,000 yrs ago

Hillside = Slice of Time
(Example: 1.00 – 0.99 million years ago)

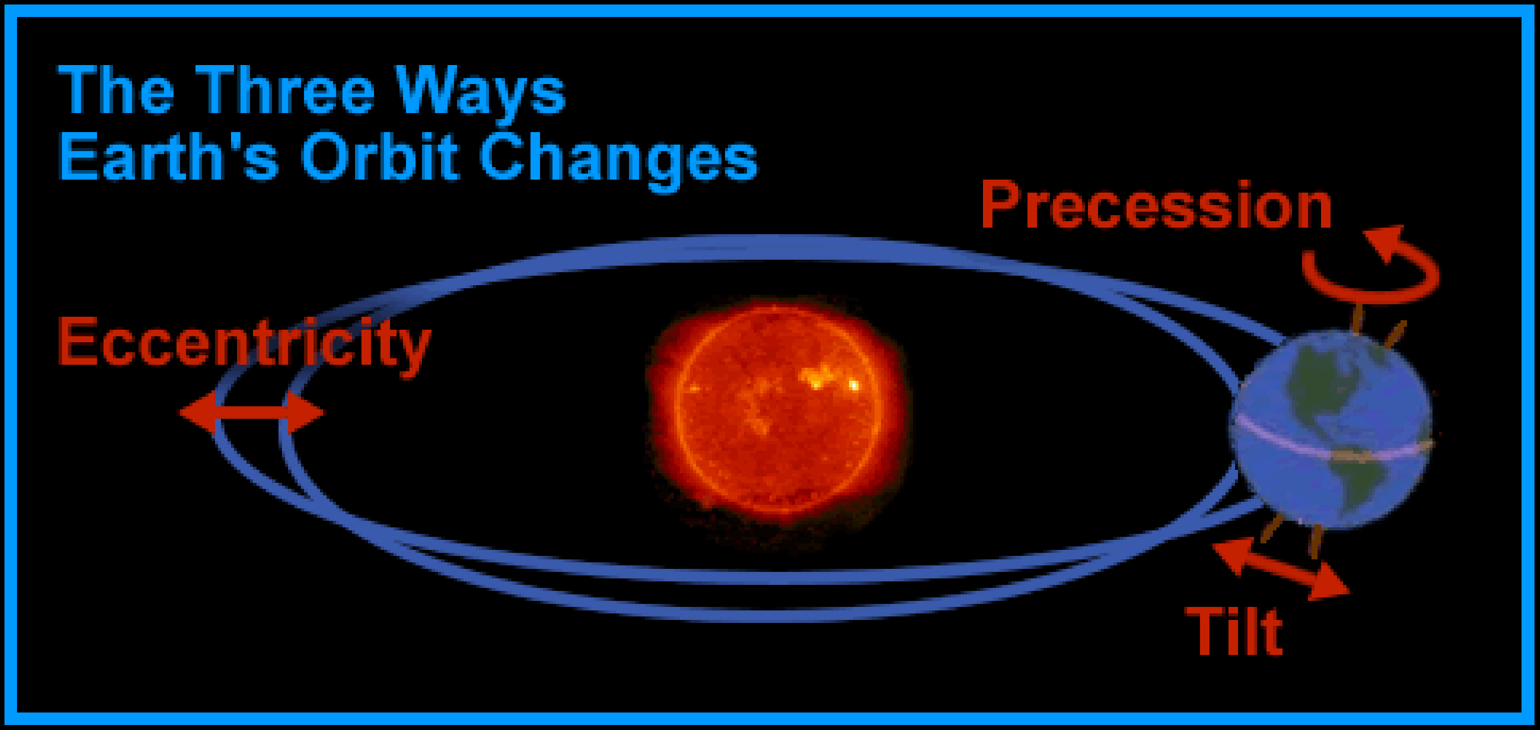




Oxygen isotope data for marine benthic foraminifera over the last 10 million years

Sapropels:

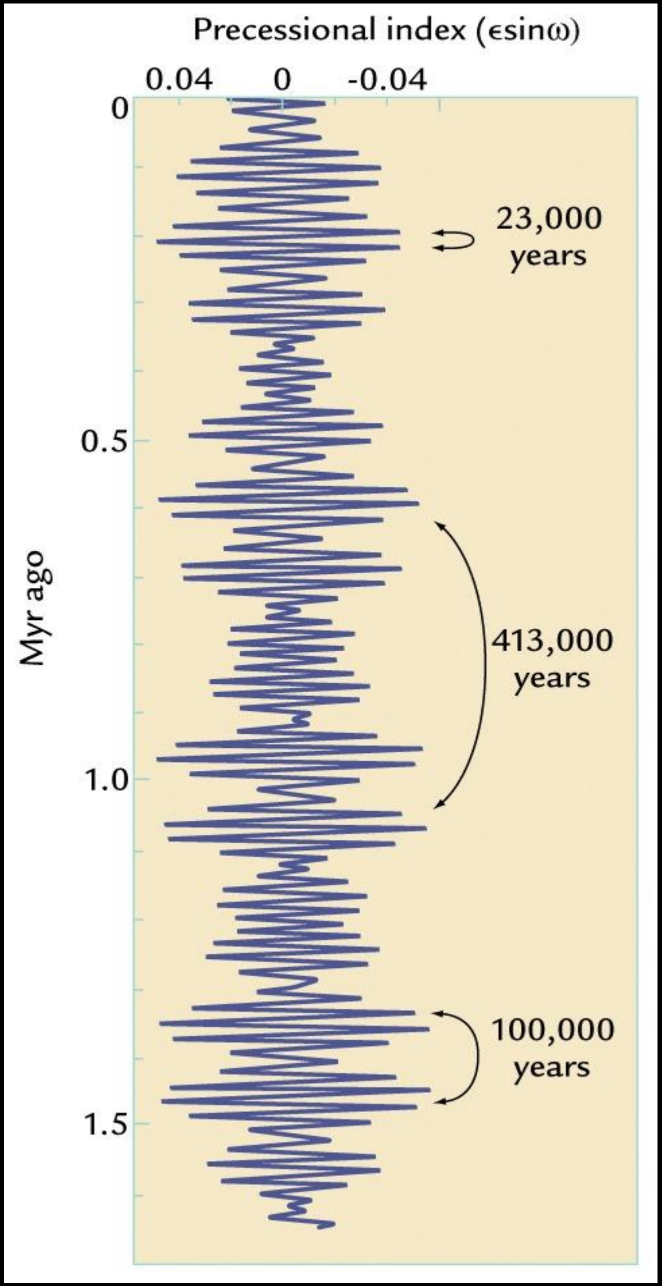
5-million-year record of tropical African moisture & aridity


The Three Ways
Earth's Orbit Changes
Precession
Eccentricity
Tilt

Tropical African climate is strongly influenced by variation in solar insolation.

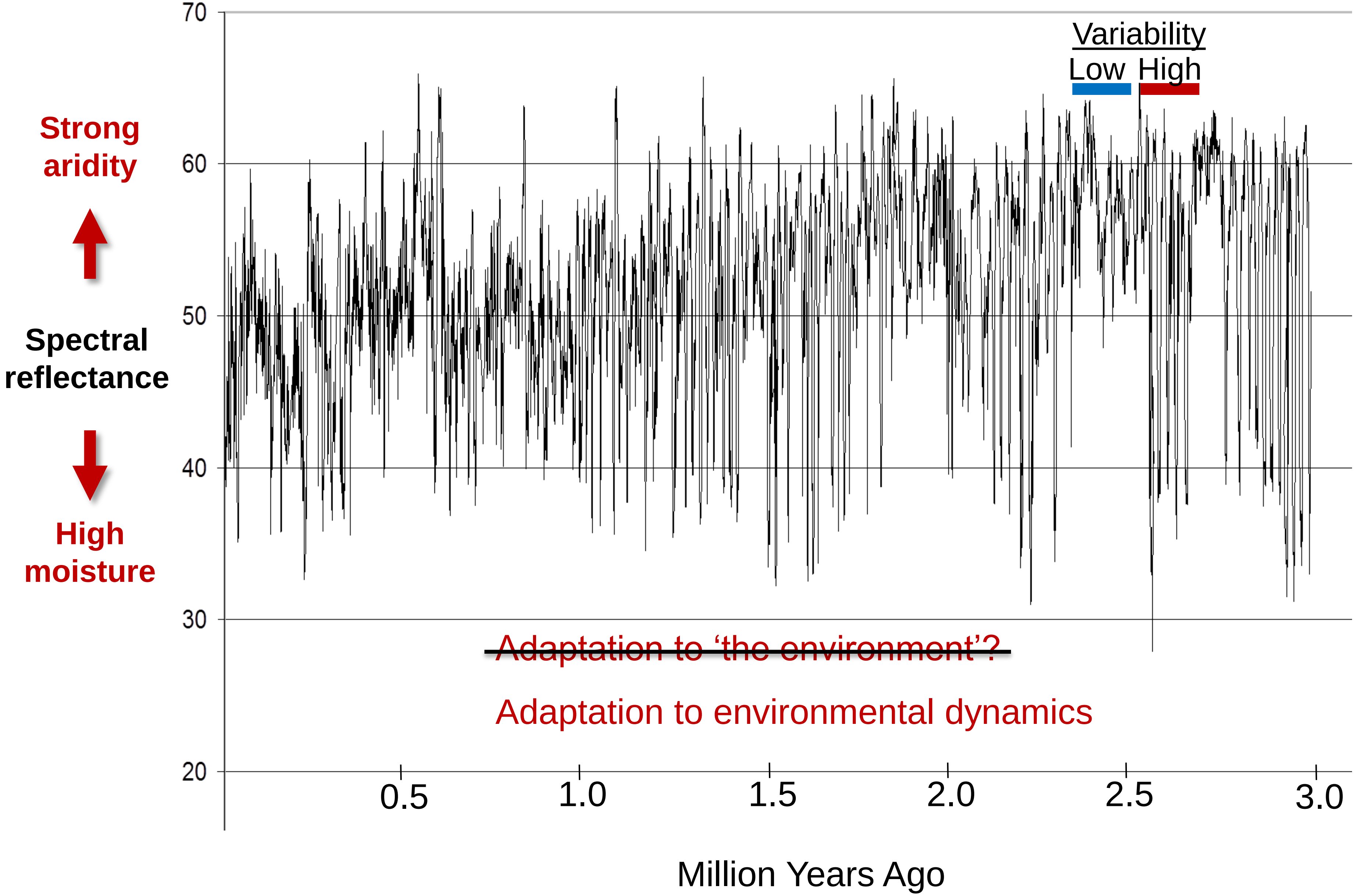
The main variation is due to the interaction of orbital precession (19,000 & 23,000-year cycles) and eccentricity (100,000 & 413,000-year cycles).

The interaction → alternating phases of high & low climate variability in tropical Africa.

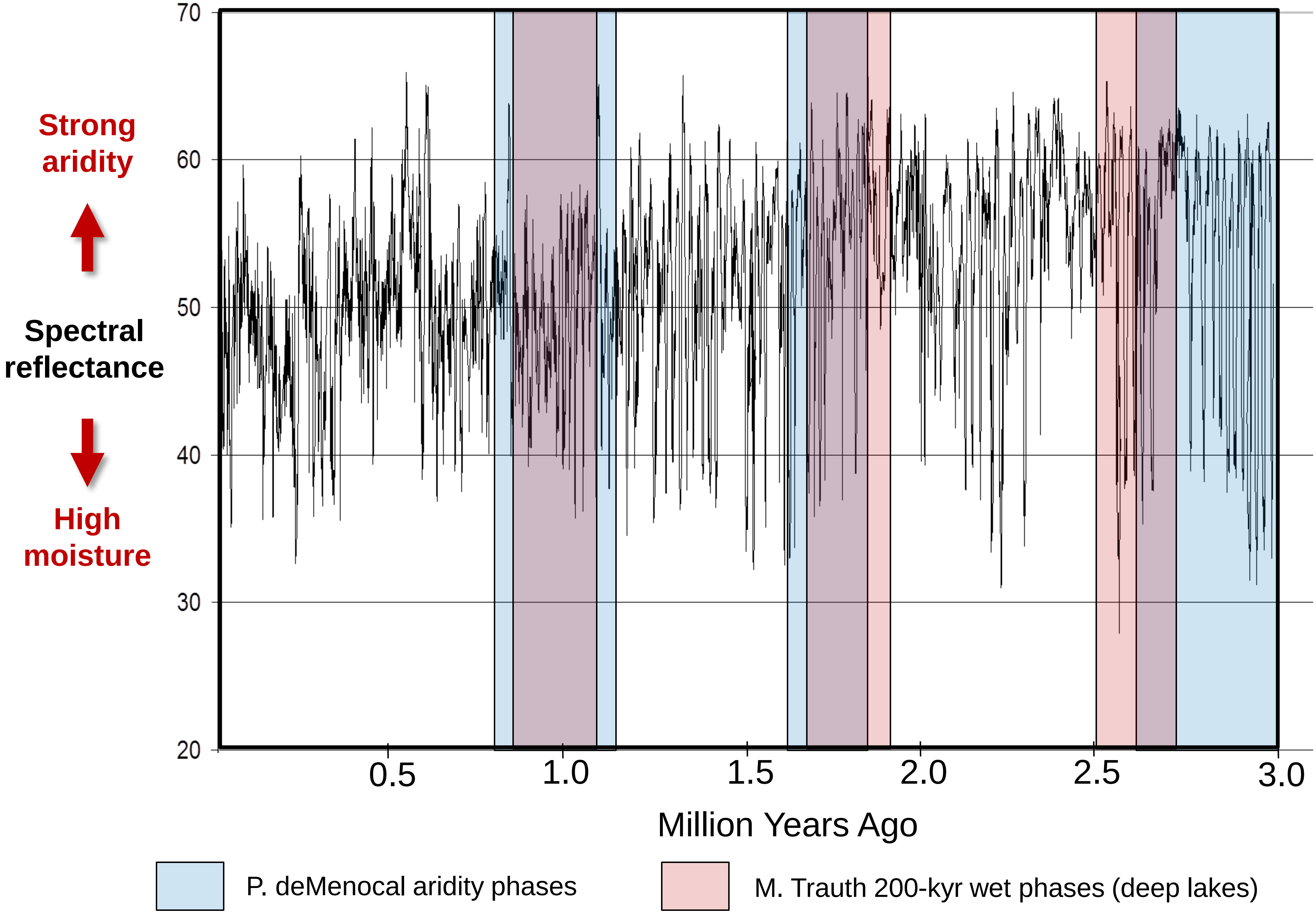


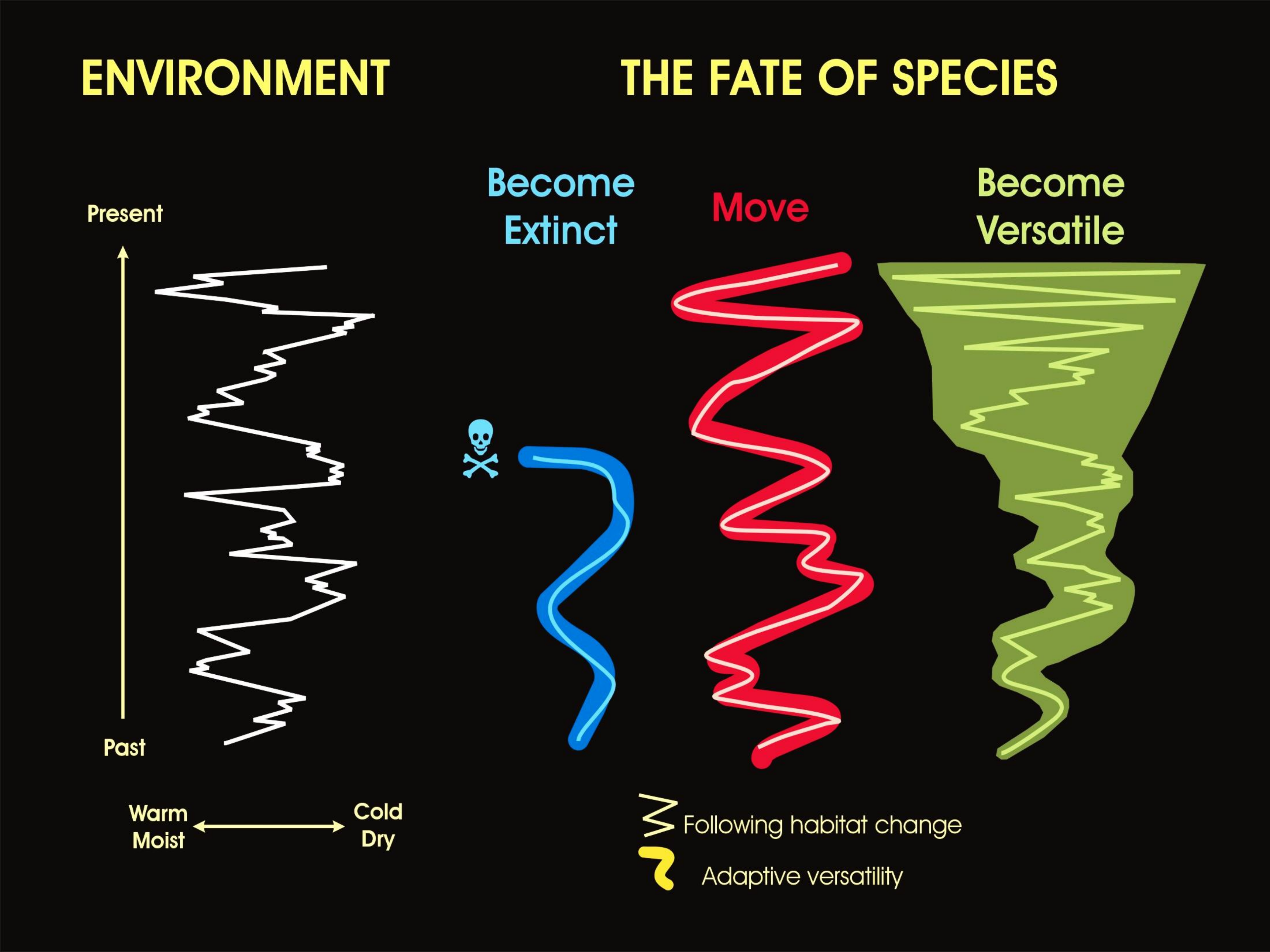
Tropical African Climate Variability

Sapropel data (Nile flooding & aridity)



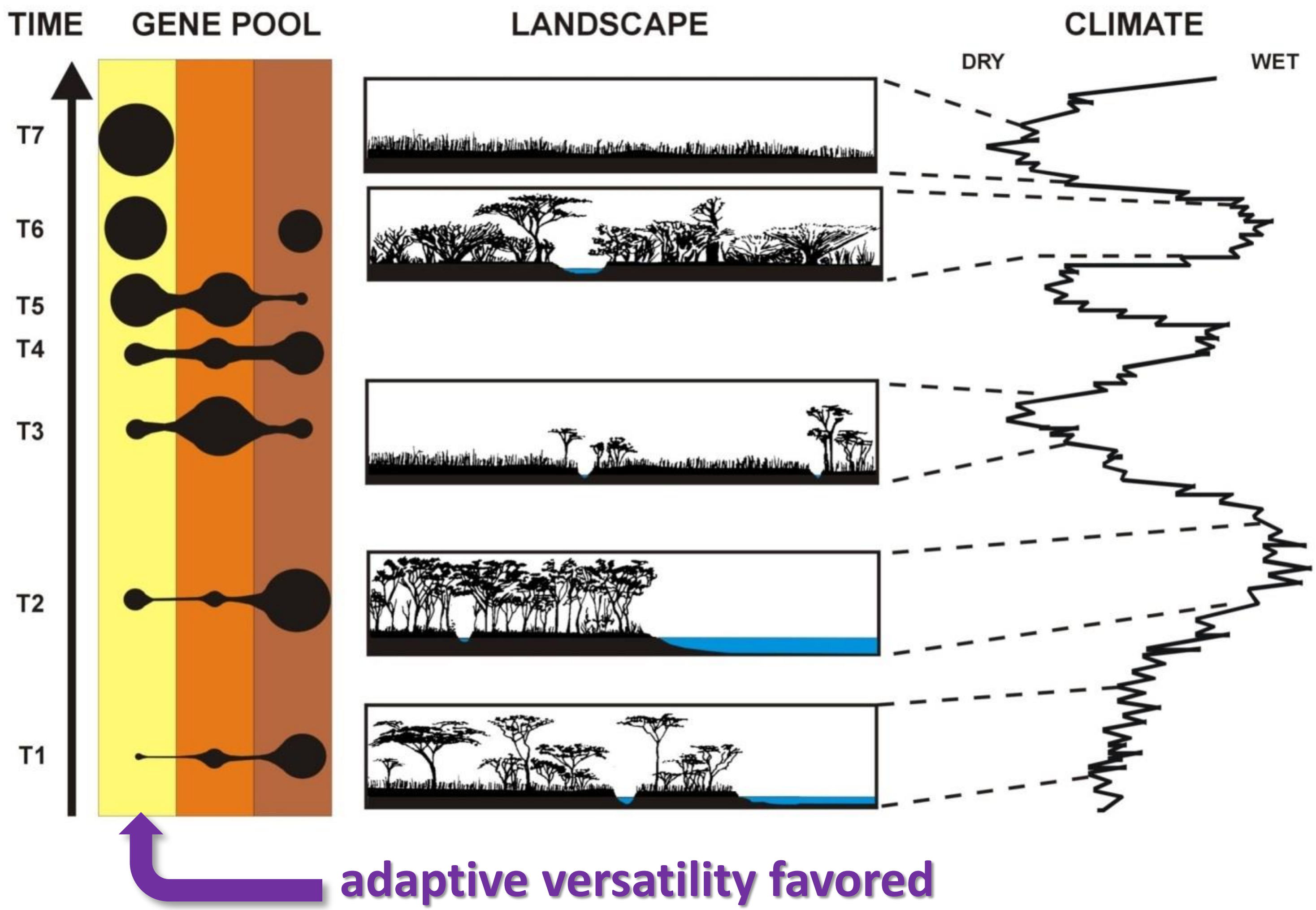
Tropical African Climate Variability
Sapropel data (Nile flooding & aridity)





ENVIRONMENT
THE FATE OF SPECIES
Present
Past
Warm
Moist
Cold
Dry
Become
Extinct
Move
Become
Versatile
Following habitat change
Adaptive versatility

Conceptual model of variability selection



Potts, 1996, *Science*

Variability selection:

A process by which particular combinations of genes are favored (increased in the gene pool) due to instability in the survival conditions over time.

The resulting adaptations enlarge the options available to the organism
(i.e., the ways in which a species uses its surroundings).

Adaptation to novelty and to *change itself*.

Environmental variability occurs at all time scales:

micro-seconds → daily → seasonal → interannual →

↕

decadal → millennial → orbital time scales

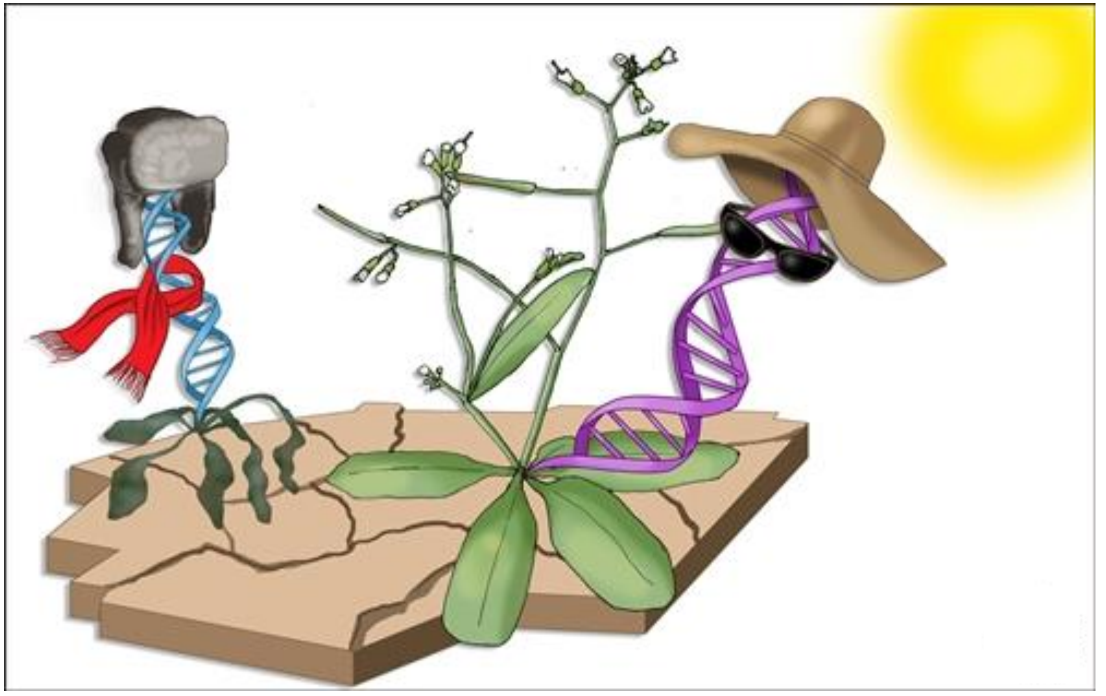
The ability to adapt to this variability (Δ variance, tempo, predictability) may be found at diverse biological levels:

Genomal organization & variation - cells –

tissue & organ systems - physiology - individual behavior -

group behavioral ecology - lineage history

Studies of *Arabidopsis thaliana*



One path to adaptability: alleles at different loci are expressed (or suppressed) in different environments

Schmitt et al., 2010, *Science*

Gene regulation is critical.
(Yes, also in the lineage of *H. sapiens*.)

Adaptation to Environmental Variability: Adventures in Experimental Evolution

C. elegans (nematodes worms):

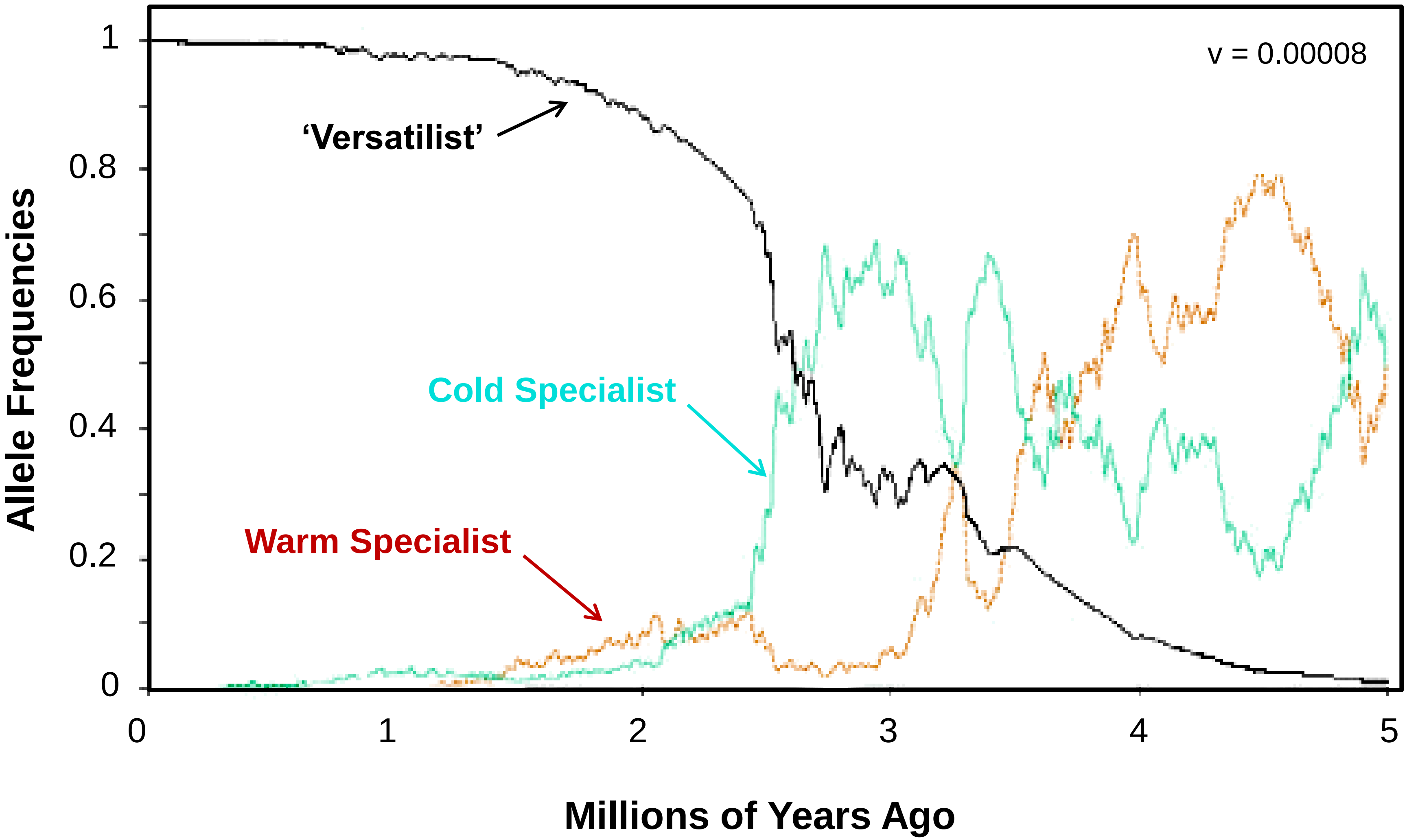
Lab populations that encountered temperature extremes at irregular intervals (160 generations) → better adapted to novel temperatures

Chiu et al., 2006, *AAPA* abstracts

B. calyciflorus (rotifers):

When exposed to highly variable & novel environments, rotifers evolved a capacity for sexual reproduction. The capacity for asexual reproduction was retained (and was elicited in homogenous environments).

Becks & Agrawal, 2010, *Nature*



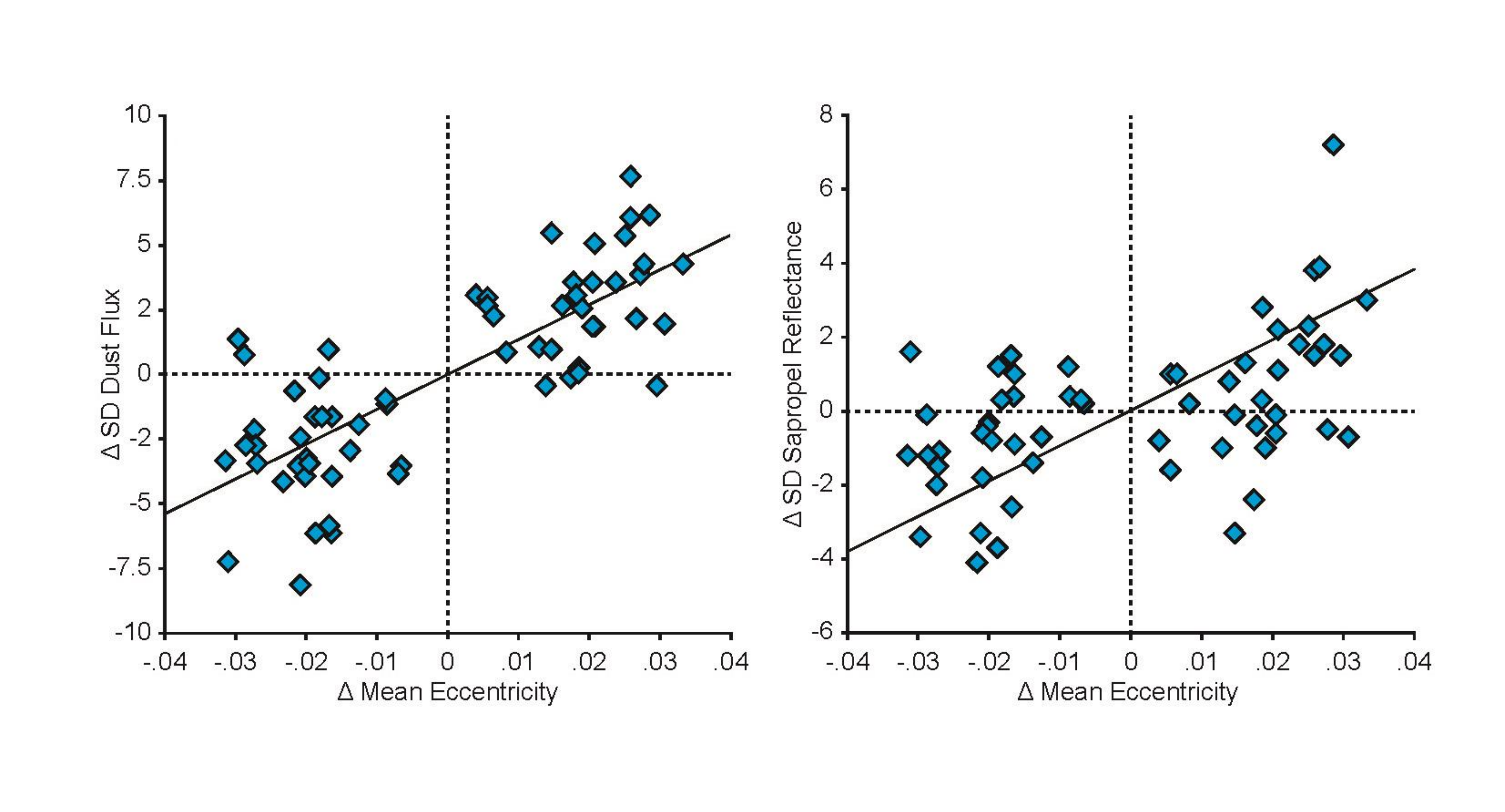
M. Grove, JHE 2011

HIGH & LOW CLIMATE VARIABILITY

Variability	Mean eccentricity	Interval (Ma)	Duration (kyr)
H14*	0.0384	**1.695 – 1.888**	**193**
L14*	0.0125	1.889 – 1.899	10
H15	0.0289	1.900 – 1.981	81
L15*	0.0115	1.982 – 2.001	19
H16*	0.0203	2.002 – 2.048	46
L16*	0.0074	2.049 – 2.079	30
H17*	0.0348	**2.080 – 2.370**	**290**
L17*	0.0081	**2.371 – 2.466**	**95**
H18*	0.0269	**2.467 – 2.795**	**328**
L18*	0.0091	**2.796 – 2.904**	**108**

Low: $\varepsilon \leq 0.0144$

* Higher or lower variability confirmed by dust flux variance



Eolian dust standard deviation
r = 0.785, p < 0.001

Sapropel standard deviation
r = 0.517, p < 0,001

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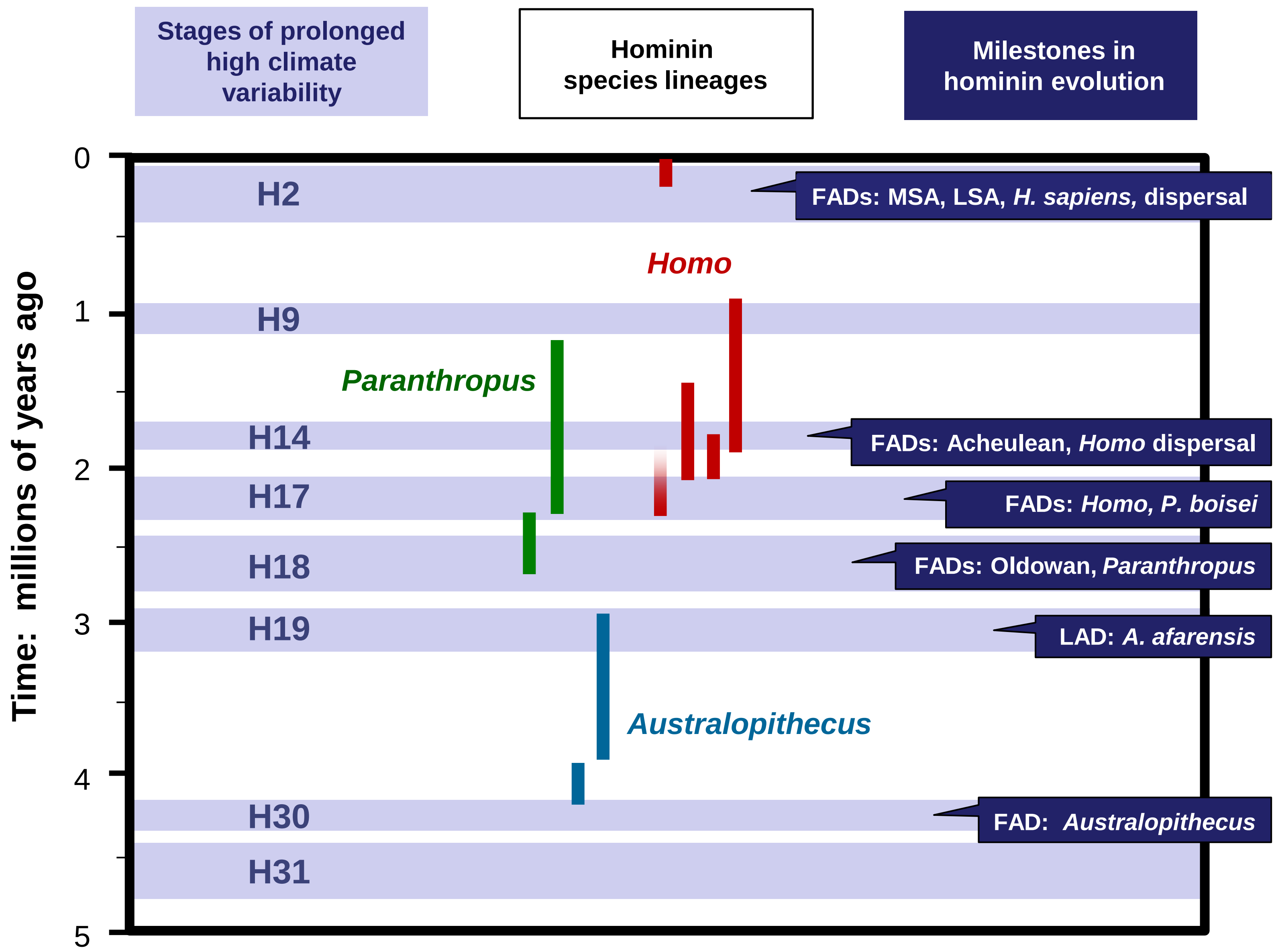

Stages of prolonged high climate variability
Hominin species lineages
Milestones in hominin evolution
Time: millions of years ago
0
1
2
3
4
5
H2
H9
H14
H17
H18
H19
H30
H31
Homo
Paranthropus
Australopithecus
FADs: MSA, LSA, *H. sapiens*, dispersal
FADs: Acheulean, *Homo* dispersal
FADs: *Homo, P. boisei*
FADs: Oldowan, *Paranthropus*
LAD: *A. afarensis*
FAD: *Australopithecus*

Oldowan Technology – the oldest known technology:
a response to environmental instability
(i.e., an increase in adaptability)

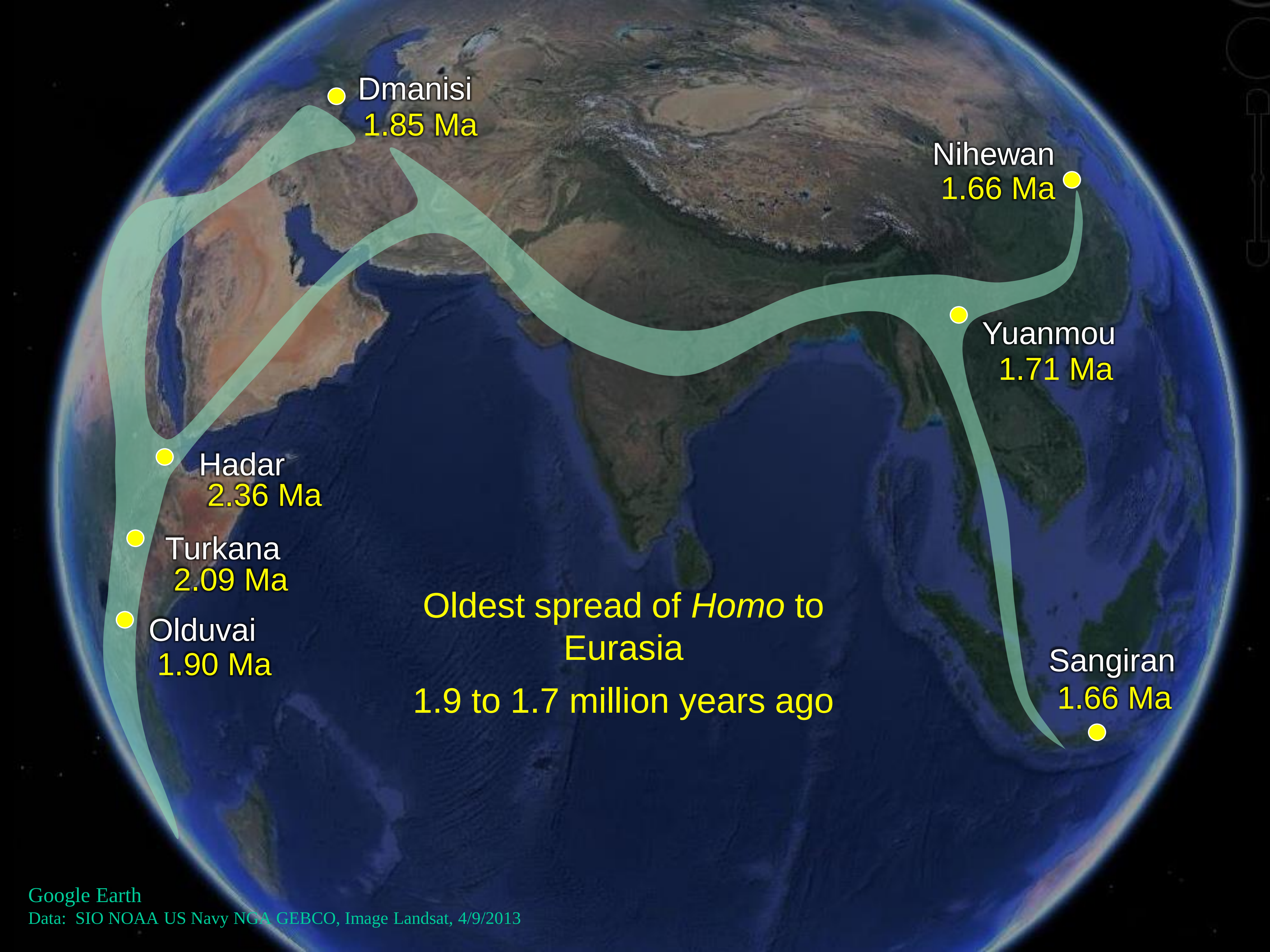
1. Stone flaking → increased the range of accessible foods.
2. Stone + food transport → buffered changes in the spatial locations & abundances of food items.
3. Access to meat/fat → helped offset habitat & resource instability.

Olduvai Gorge, Tanzania
1.85 million years old

Kanjera South, Kenya
2 million years old

Kanjera South, western Kenya: ~2.0 million years old

- The first tool kit: hammerstones, flakes, & cores
- Carrying stones up to 12 km
- A change to a diet rich in meat & tubers


Dmanisi
1.85 Ma
Nihewan
1.66 Ma
Yuanmou
1.71 Ma
Hadar
2.36 Ma
Turkana
2.09 Ma
Olduvai
1.90 Ma
Sangiran
1.66 Ma
Oldest spread of *Homo* to Eurasia
1.9 to 1.7 million years ago
Google Earth
Data: SIO NOAA US Navy NGA GEBCO, Image Landsat, 4/9/2013

ADAPTABILITY

Adaptability: The ability of an organism …

… to endure change in the environment.

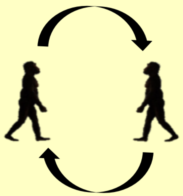
… to thrive in novel environments.

… to spread to new habitats.

… to respond in new ways to the surroundings.

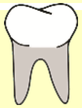
TIME	EVOLUTIONARY CHANGE	ADAPTIVE BENEFITS
100 ka to present	Increased cultural diversity & technological innovation	Expanded range of adaptive options
by 250 ka	Enhanced symbolic behavior	Greater capacity to imagine, plan, & communicate novel ideas
by 250 ka	Complex spatial mapping & resource exchange	Enlarged store of information about the ecological & social surroundings
by 800 - 400 ka	Controlling fire & building shelters	Food sharing at home bases: enhanced social memory & buffering of uncertainty
800 - 200 ka	Most rapid increase in relative brain size	Expanded memory & processing of data about the surroundings
by 1.7 Ma	Initial advances in stone technology	Increased ability to use & modify the environment
by 2.0 – 1.5 Ma	Pronounced elongation of the legs	Enhanced mobility & dispersal capability
by 2.0 Ma	Extensive carrying of stones & food	Improved ability to adjust to changes in food availability & spatial distribution
by 2.6 Ma	Simple stone flaking	Expanded ability to process new foods, like meat, marrow, & underground plants
by 4 – 3 Ma	Increased diversity in tooth microwear	Improved access to diverse foods
~6 – 2 Ma	Bipedal walking & tree climbing	Versatile movement in wooded & open environments











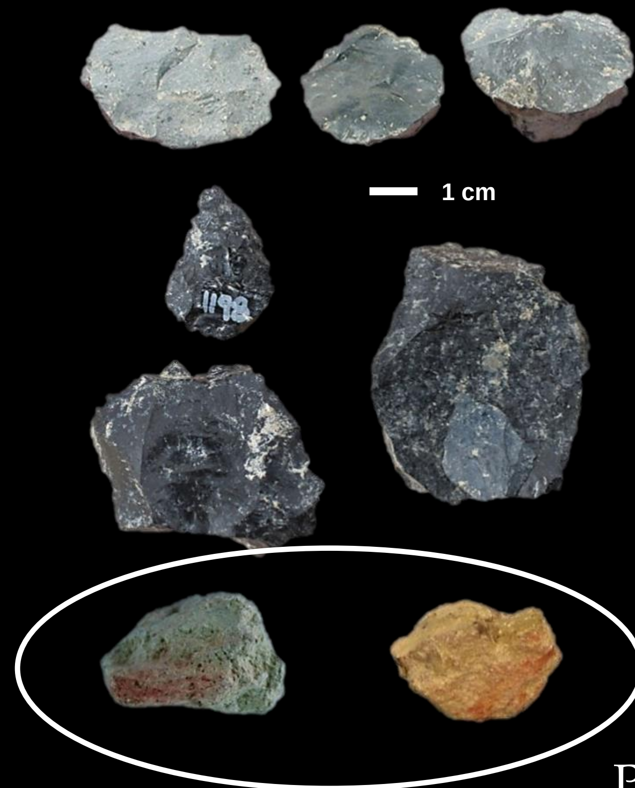
Olorgesailie

1.7 million - 500,000 years ago

Acheulean handaxes

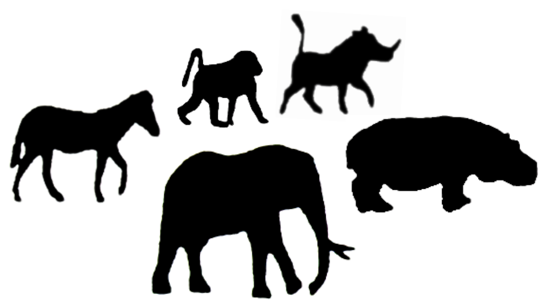
By 320,000 years ago

Middle Stone Age innovations



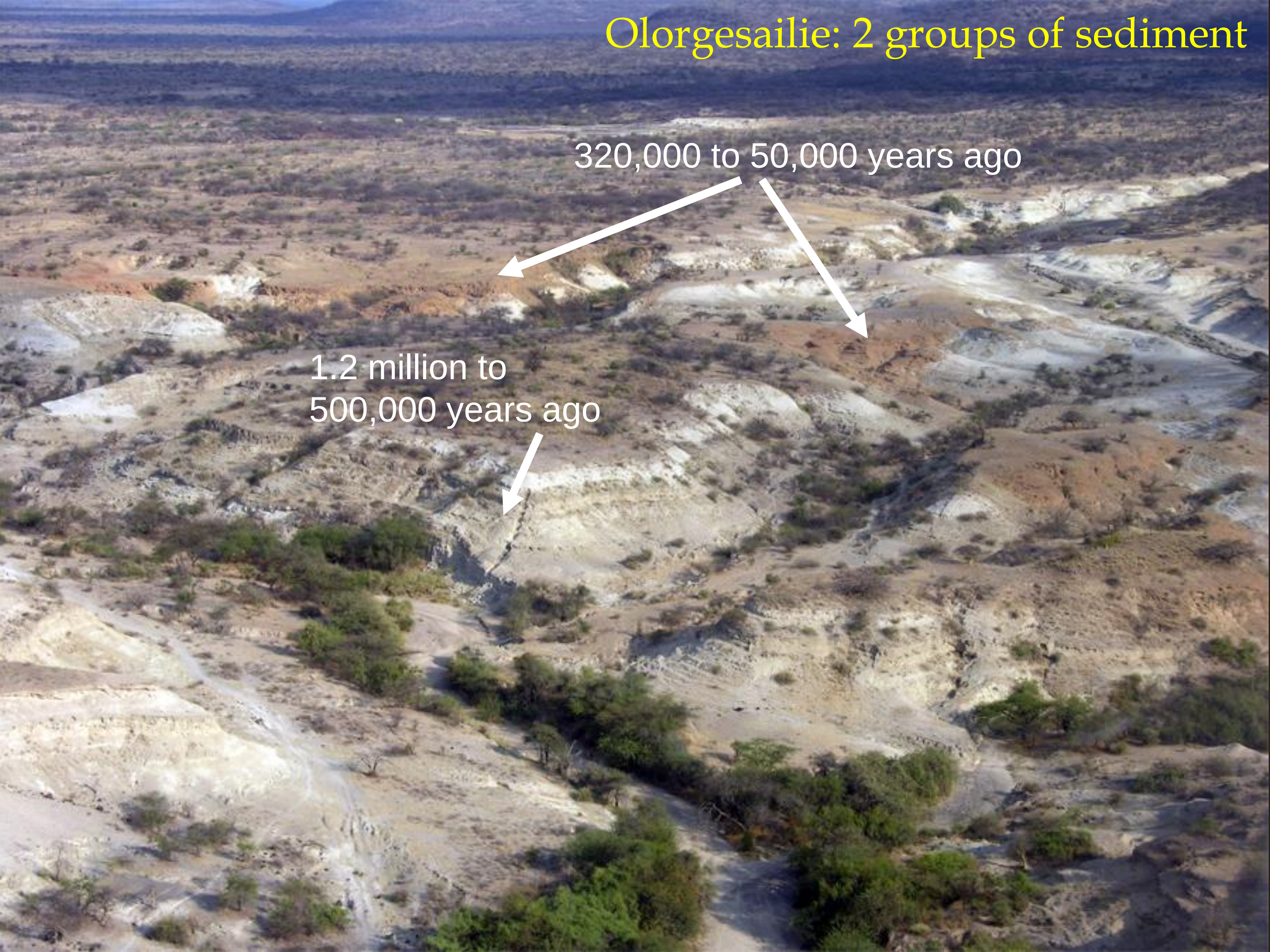
Pigments

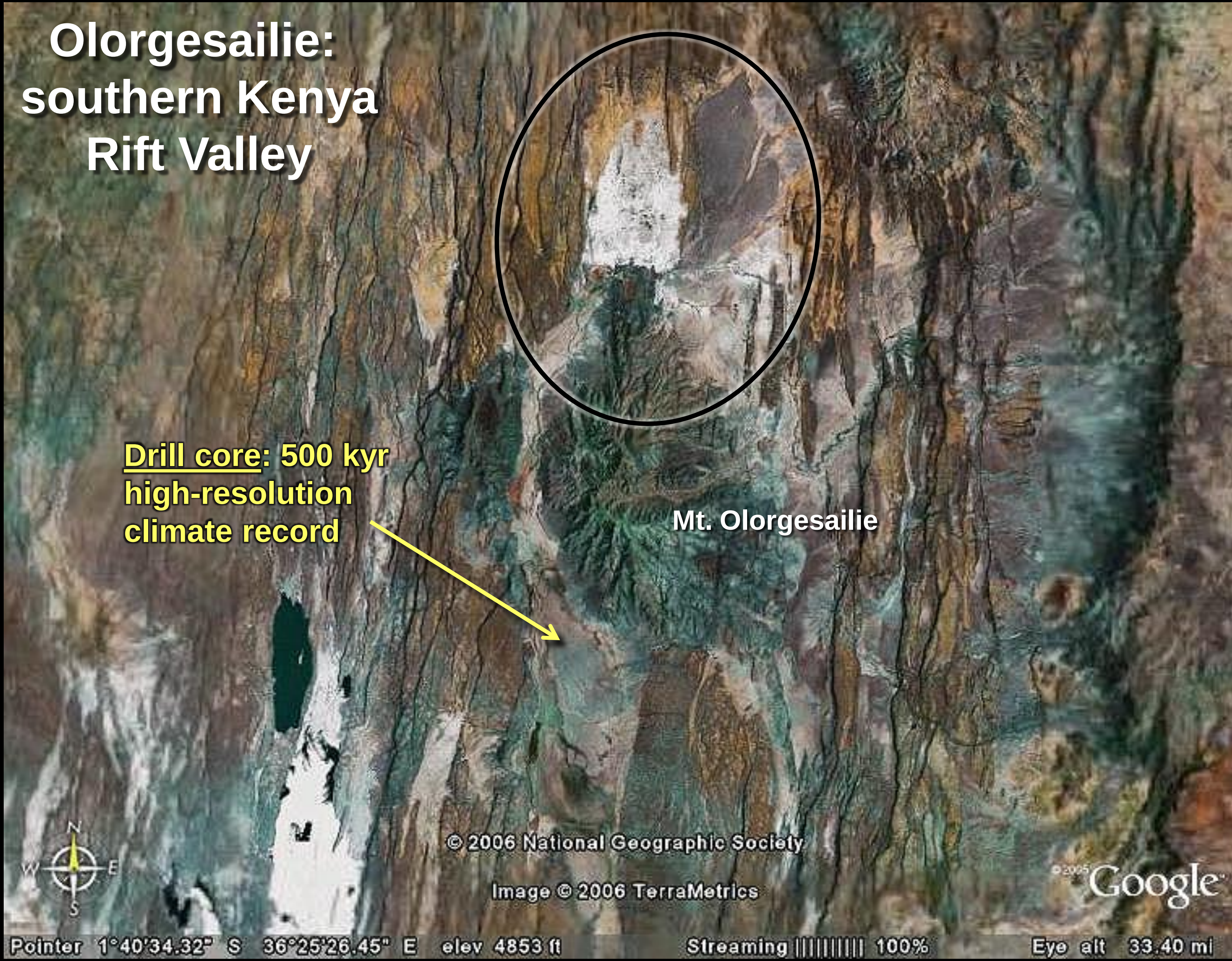
Extinct Species



Modern Species

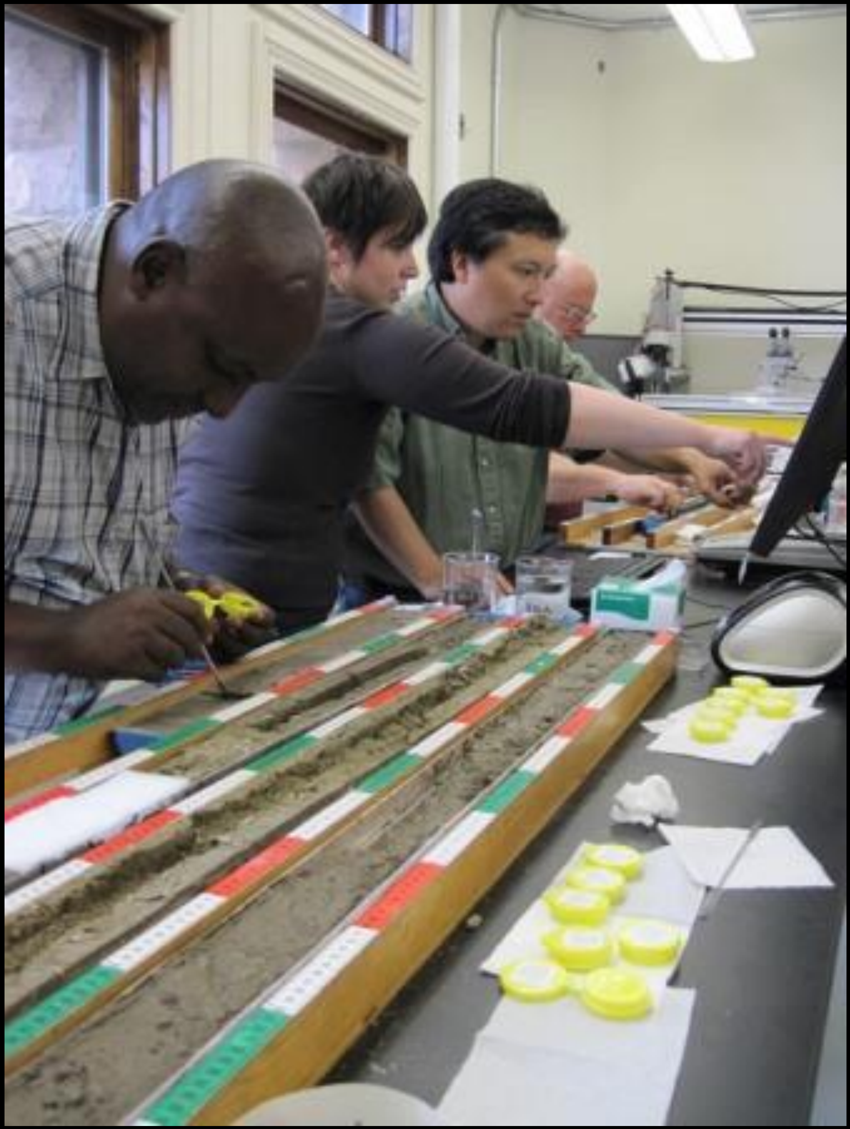
Olorgesailie: 2 groups of sediment




Olorgesailie:
southern Kenya
Rift Valley
Drill core: 500 kyr
high-resolution
climate record
Mt. Olorgesailie
© 2006 National Geographic Society
Image © 2006 TerraMetrics
Google
N
W
E
S
Pointer 1°40'34.32" S 36°25'26.45" E elev 4853 ft
Streaming |||||||||| 100%
Eye alt 33.40 mi

Olorgesailie Drilling Project

216m sediments ~ the past 500 kyr

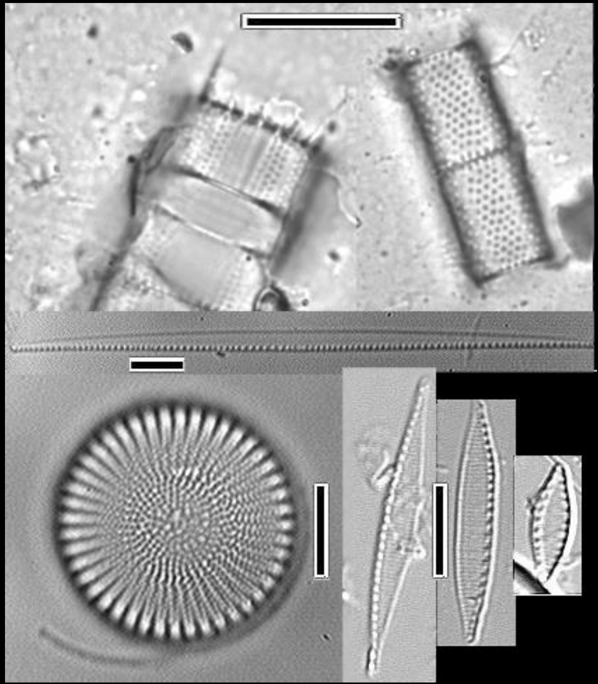


Olorgesailie Drilling Project

Kay Behrensmeyer

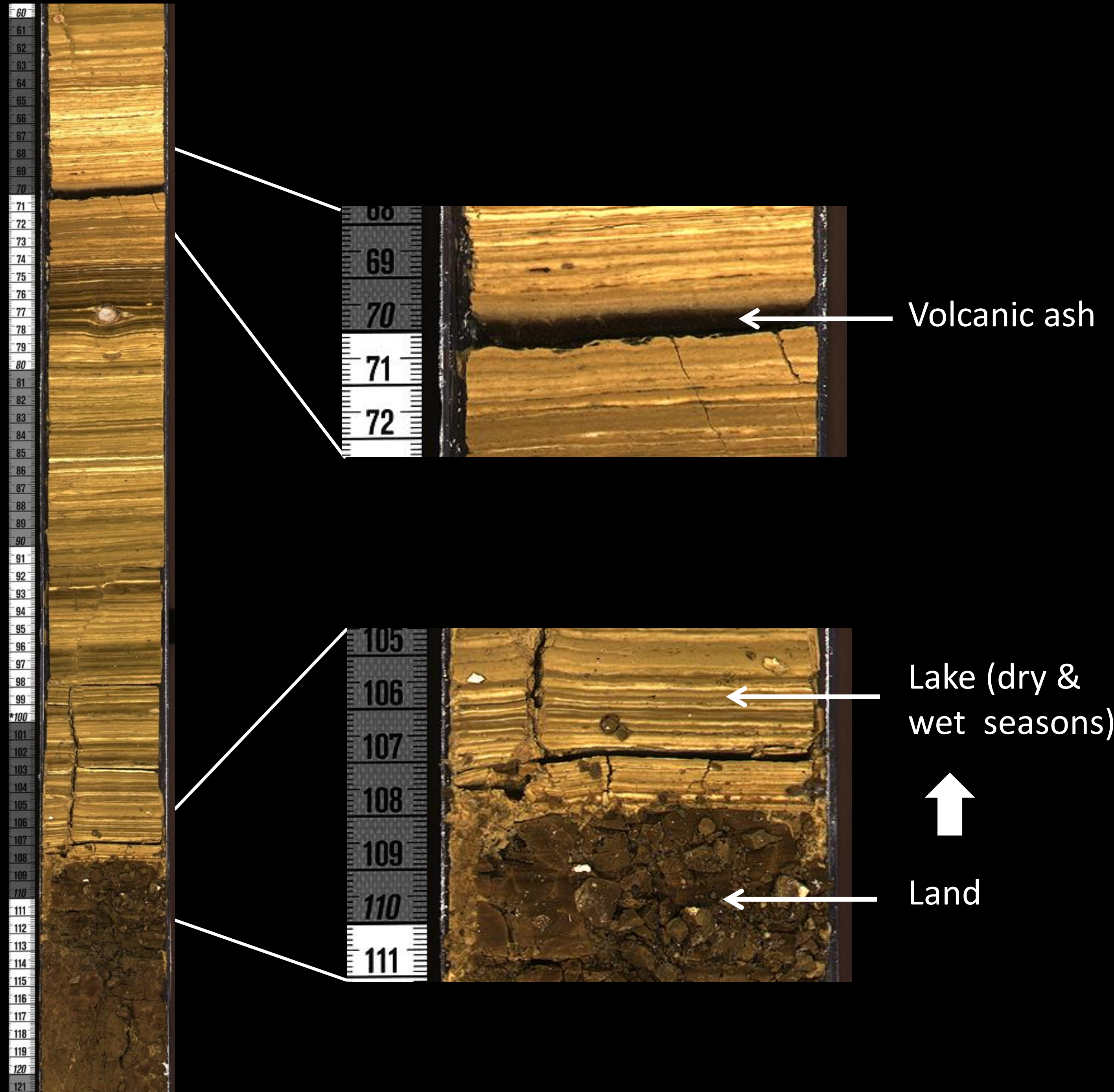
René Dommain
Bernie Owen

Lake diatoms

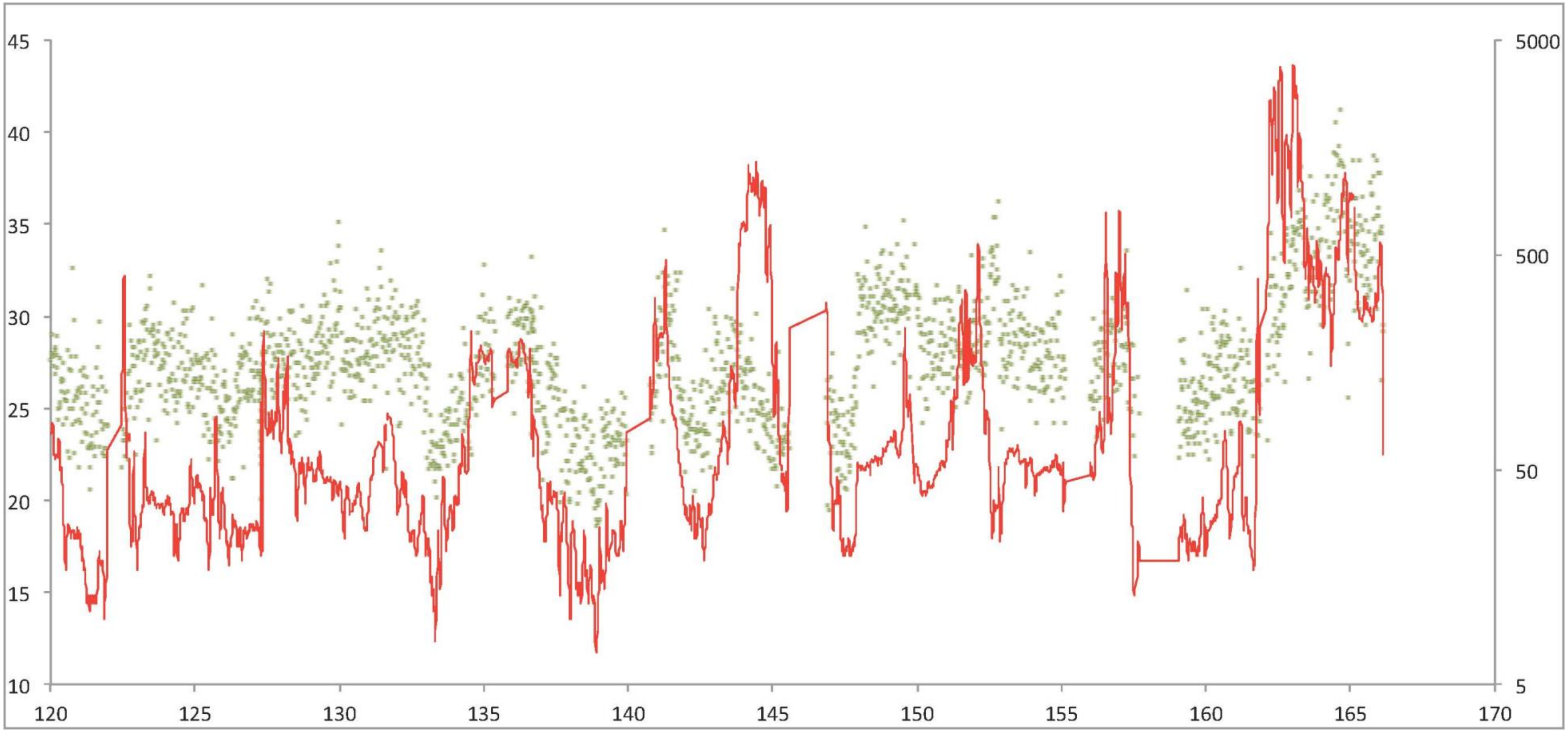


Olorgesailie Drilling Project

Peter deMenocal, Stephen Rucina, Alan Deino


Volcanic ash
Lake (dry &
wet seasons)
Land

Magnetic susceptibility & Gamma radiation analysis
Core 1A: 120 – 166m



Goal: Investigate the environmental conditions associated with the emergence of *Homo sapiens*:

500,000 – 300,000 yrs ago: Transition from handaxe technology to innovative Middle Stone Age behaviors, including new tool kits & pigments (Olorgesailie)

500,000 – 300,000: Emergence of the modern African large mammal biota (Olorgesailie, Lainyamok)

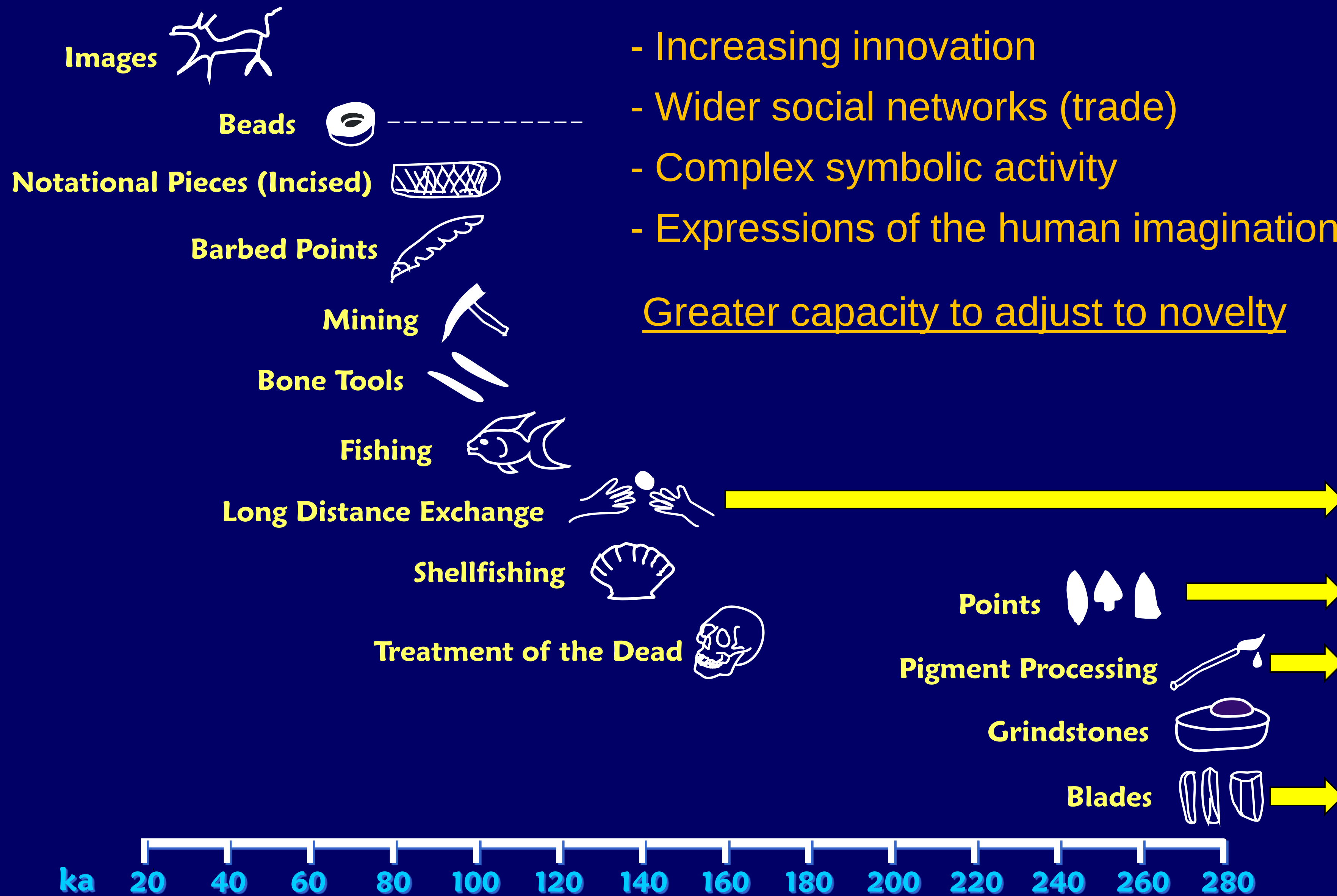
By ~200,000 yrs ago: First appearance of *H. sapiens*
(Fossils: Omo Kibish Genomics: E. Africa)

100,000 – 60,000 yrs ago: Low population size (genetic bottleneck?), followed by expansion & dispersal

Behavioral Innovations of the Later Pleistocene in Africa

- Increasing innovation
- Wider social networks (trade)
- Complex symbolic activity
- Expressions of the human imagination

<u>Greater capacity to adjust to novelty</u>



(From: McBrearty & Brooks, 2000)

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