

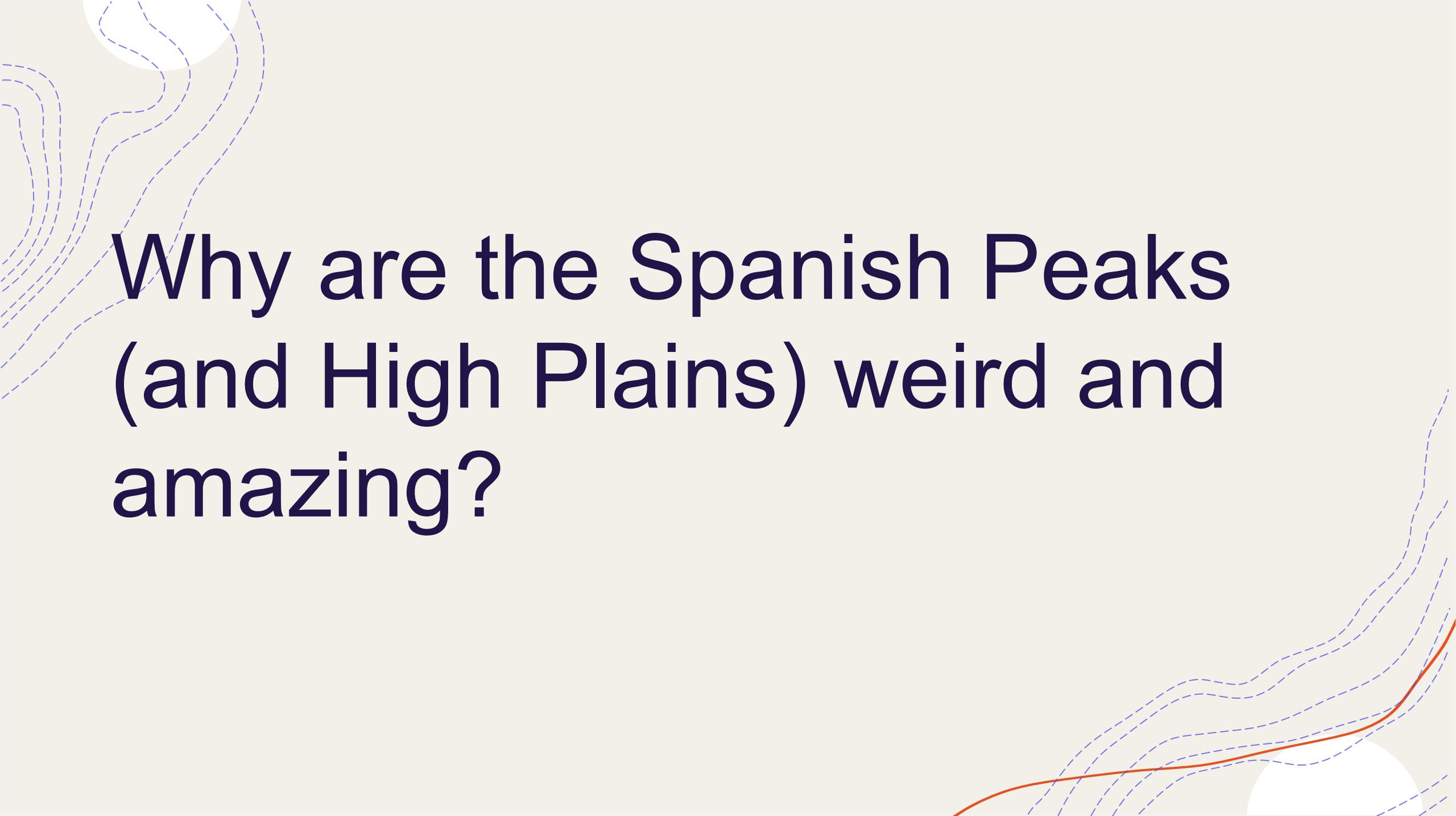
Geologic Origins of the Spanish Peaks and High Plains

+
© Sabrina Kainz and Lon Abbott (CU Boulder)

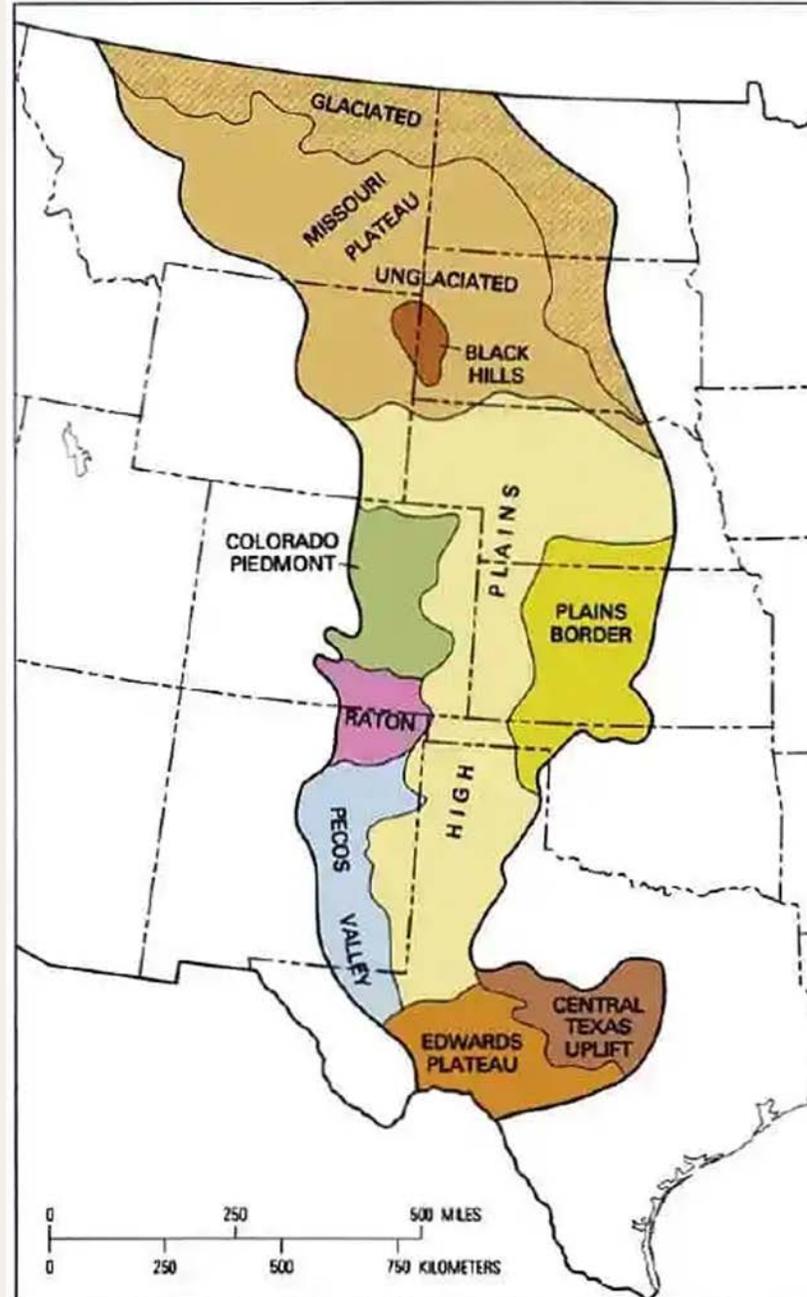
A Tried and True Landmark



“Wahatoya”
Double Mountain in Comanche



Why are the Spanish Peaks
(and High Plains) weird and
amazing?

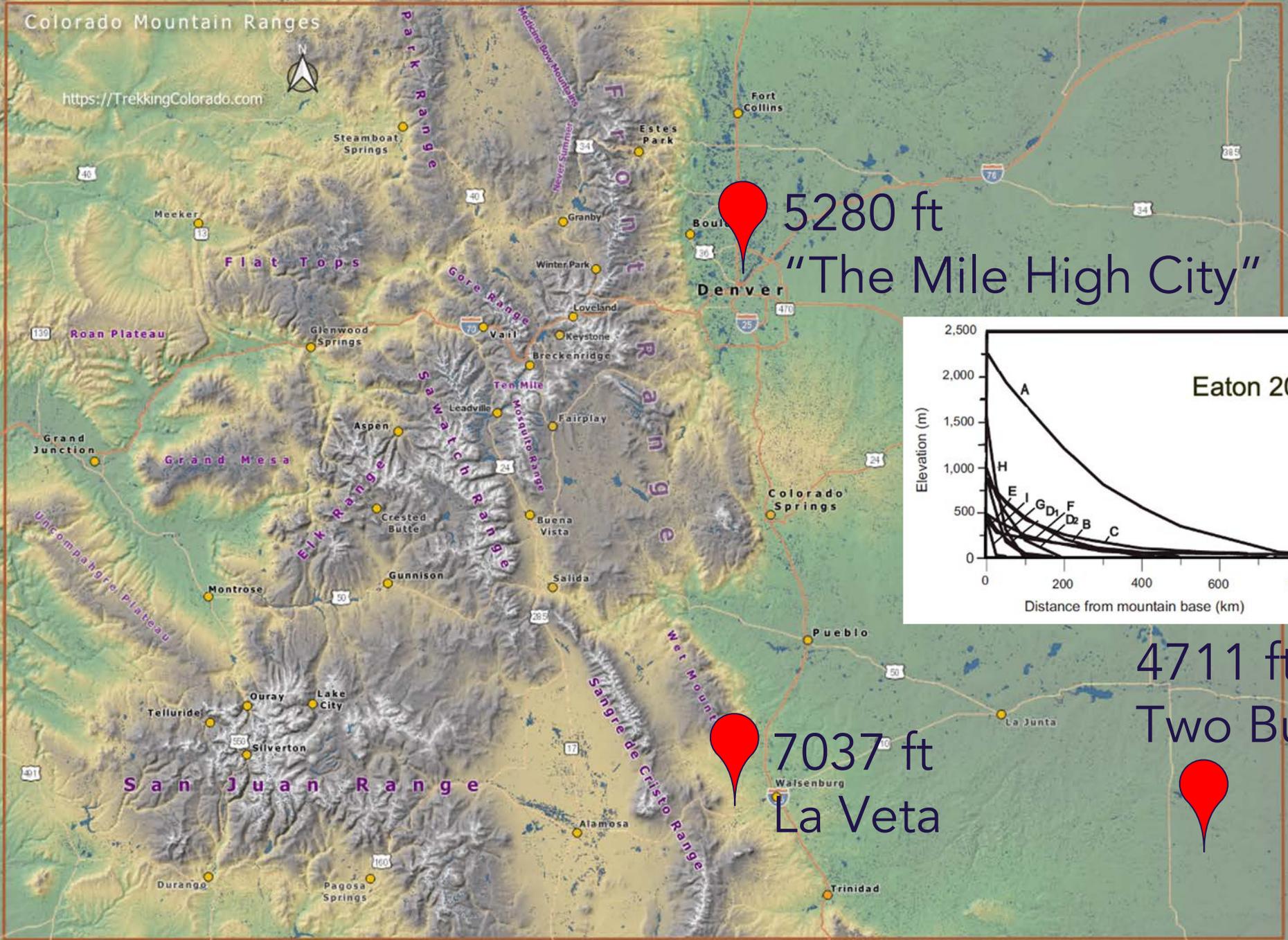


Source: Trimble, D., U.S. Geological Survey, Geological Survey Bulletin 1493, 1980.

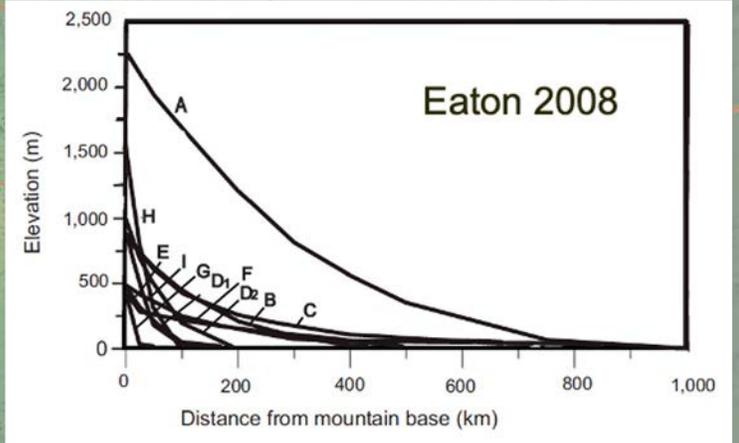
The High Plains Geographic Region

Colorado Mountain Ranges

<https://TrekkingColorado.com>



5280 ft
"The Mile High City"



7037 ft
La Veta

4711 ft
Two Buttes



Colorado Mountain Ranges

<https://TrekkingColorado.com>



How and when did the High Plains and Rocky Mountains get high?



5280 ft

"The Mile High City"

Denver



7037 ft

La Veta

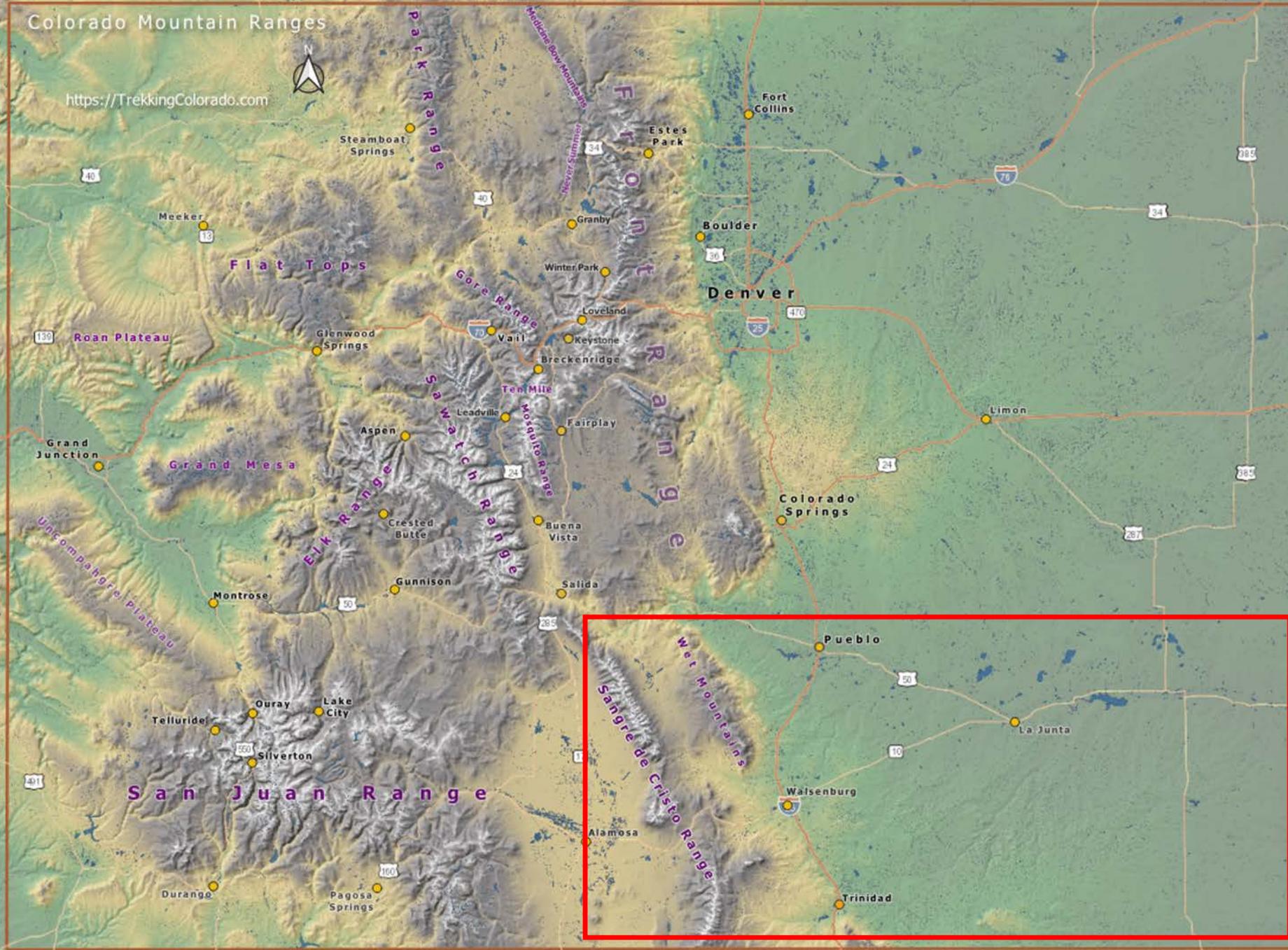
4711 ft

Two Buttes



Colorado Mountain Ranges

<https://TrekkingColorado.com>





Saguache

Westcliffe

Fowler

Crestone

Colorado City

Center

Walsenburg

Monte Vista



La Veta

Alamosa

Fort Garland

Aguilar

La Jara

Manassa

San Luis

Trinidad



**Wet
Mountains**

**Sangre de Cristo
Mountains**

Spanish Peaks

Saguache

Crestone

Westcliffe

Fowler

Colorado City

Center

Walsenburg

Monte Vista

Alamosa

Fort Garland

La Veta

Aguilar

La Jara

Manassa

San Luis

Trinidad



Geology's Fourth Dimension: Time

Today

Age of Earth (4.6 billion years)



Colorado's Geologic History

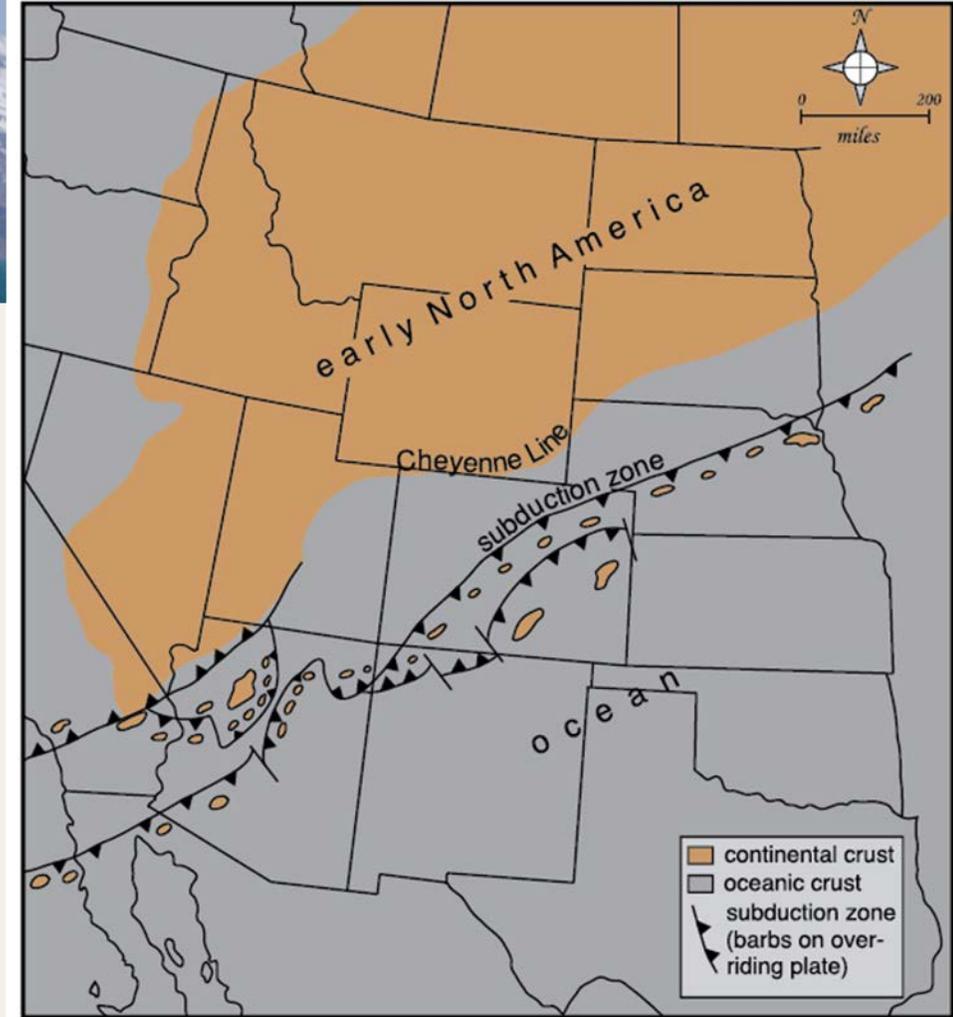
Today



Colorado's Basement Forms (1.8 billion years ago)

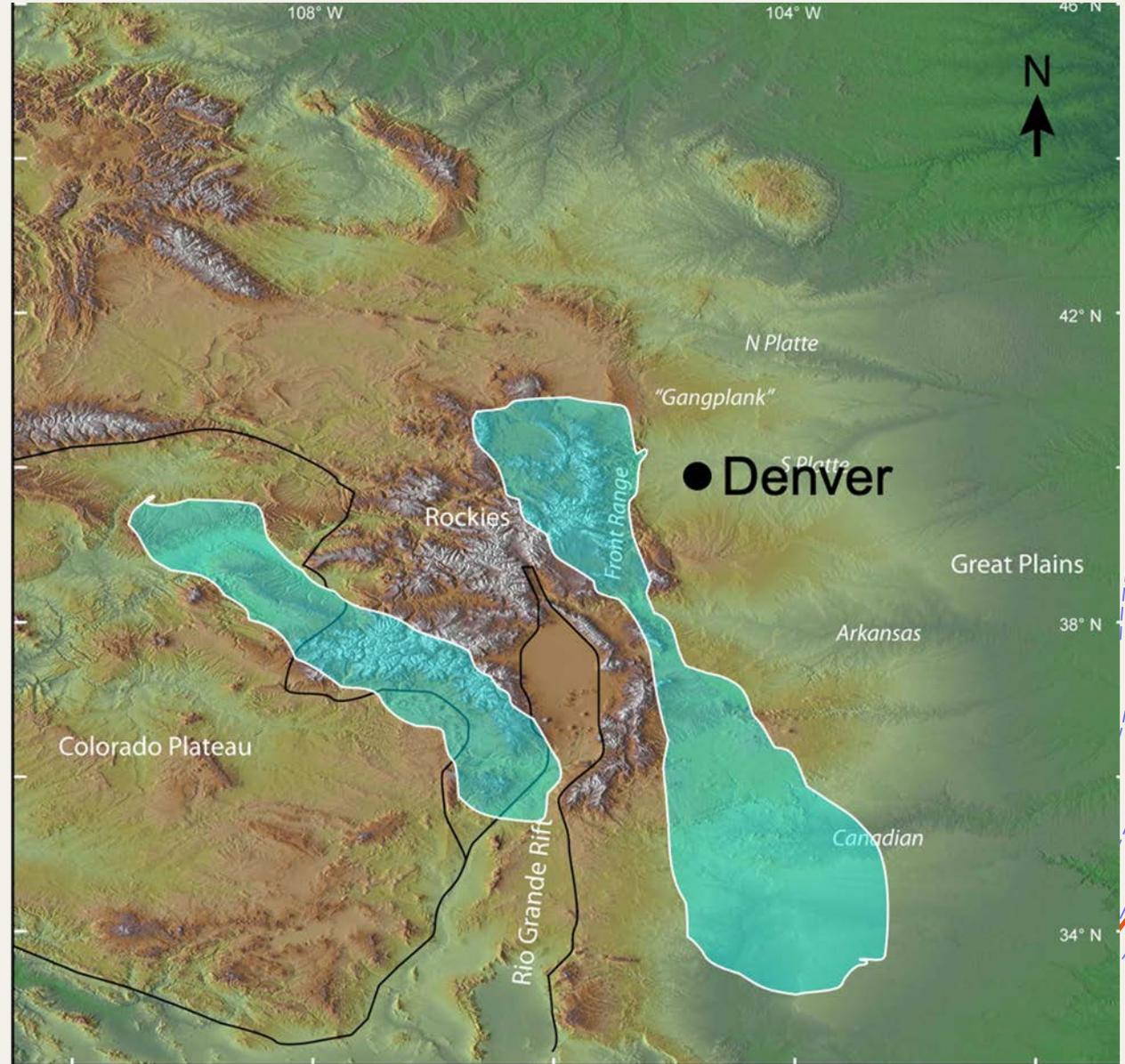


Age of Earth (4.6 billion years)



Colorado's Geologic History

Today

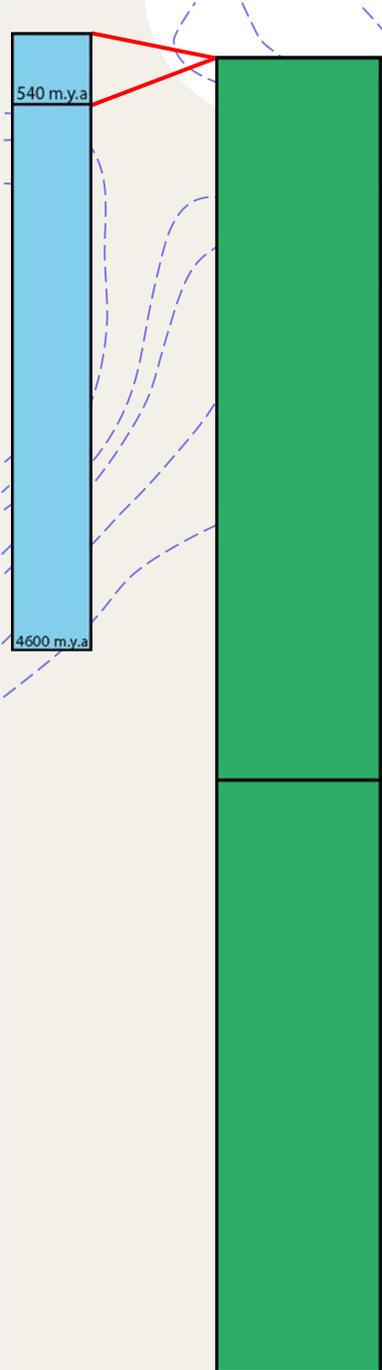


Ancestral
Rocky Mountains
(300 million years ago)



A. Modern reconstruction of Pangaea
Copyright © 2008 Pearson Prentice Hall, Inc.

Complex animal life evolves (540 million years ago)



Colorado's Geologic History

Today

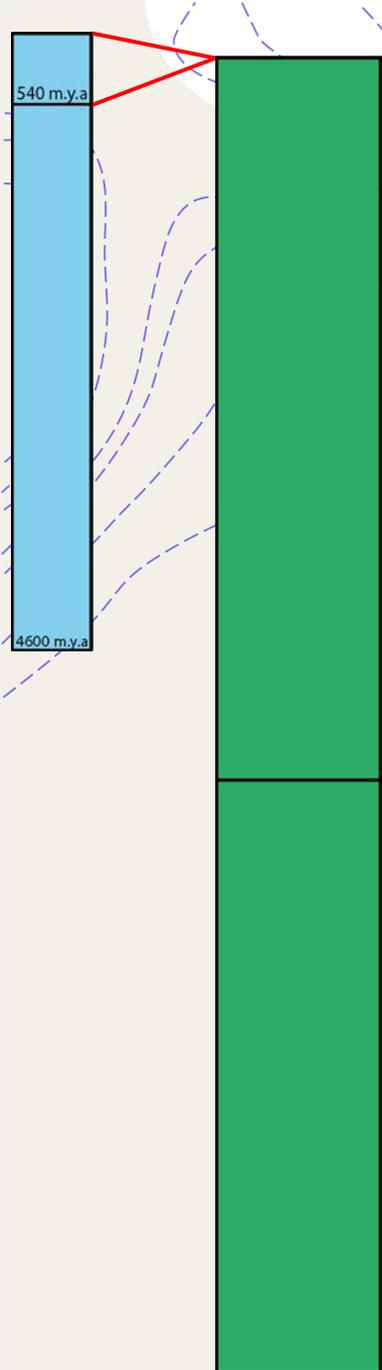
Sangre de Cristo Range



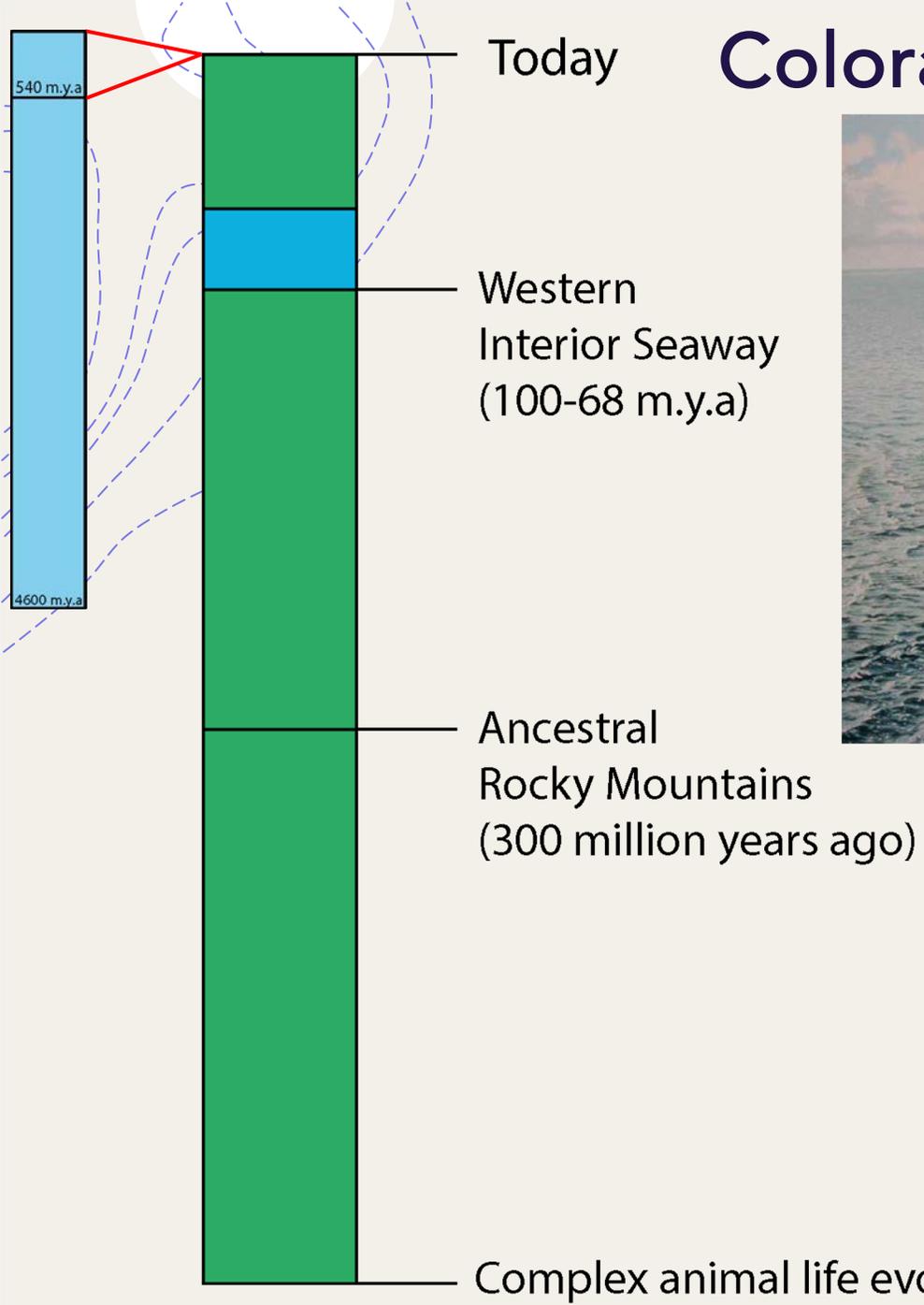
Ancestral
Rocky Mountains
(300 million years ago)



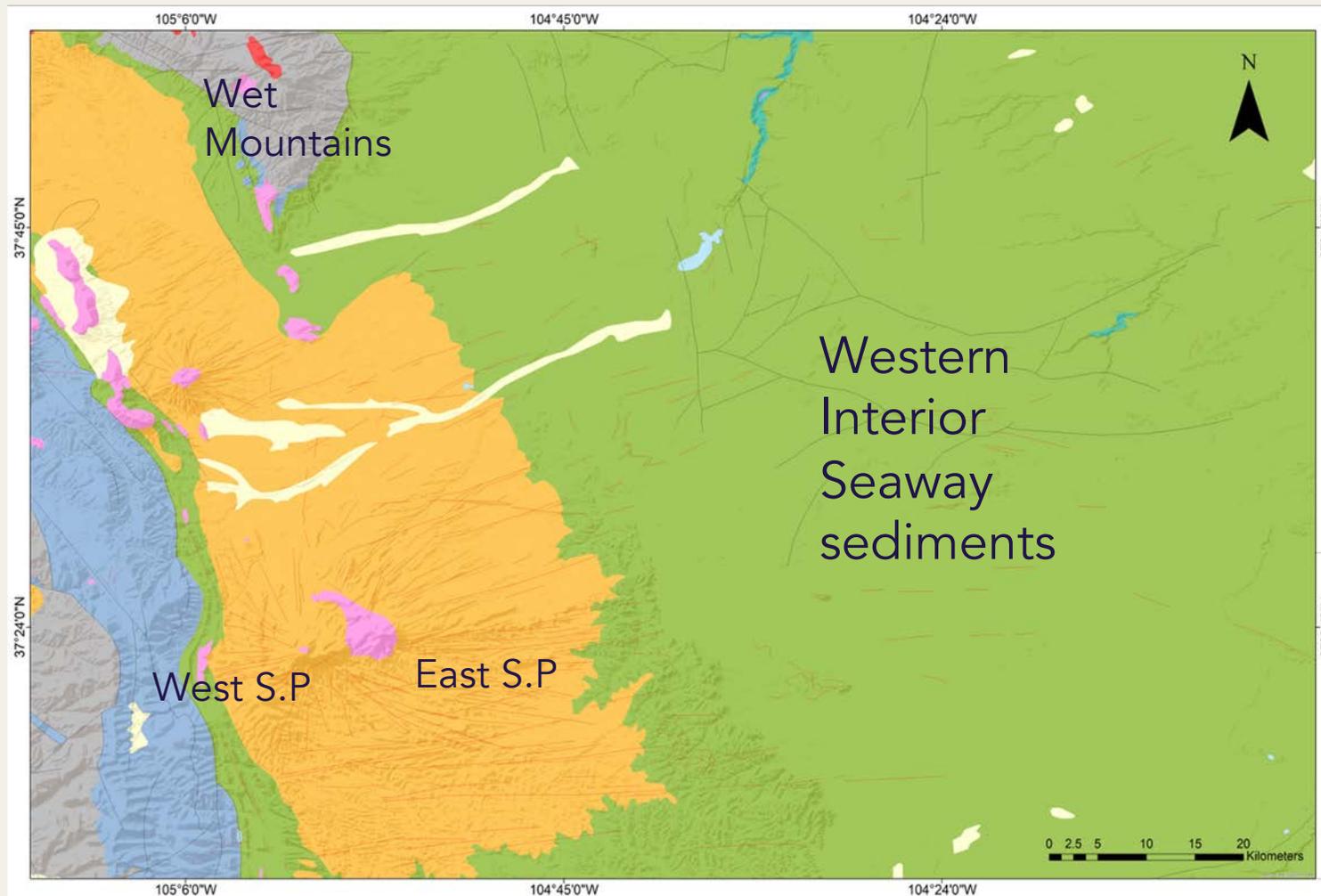
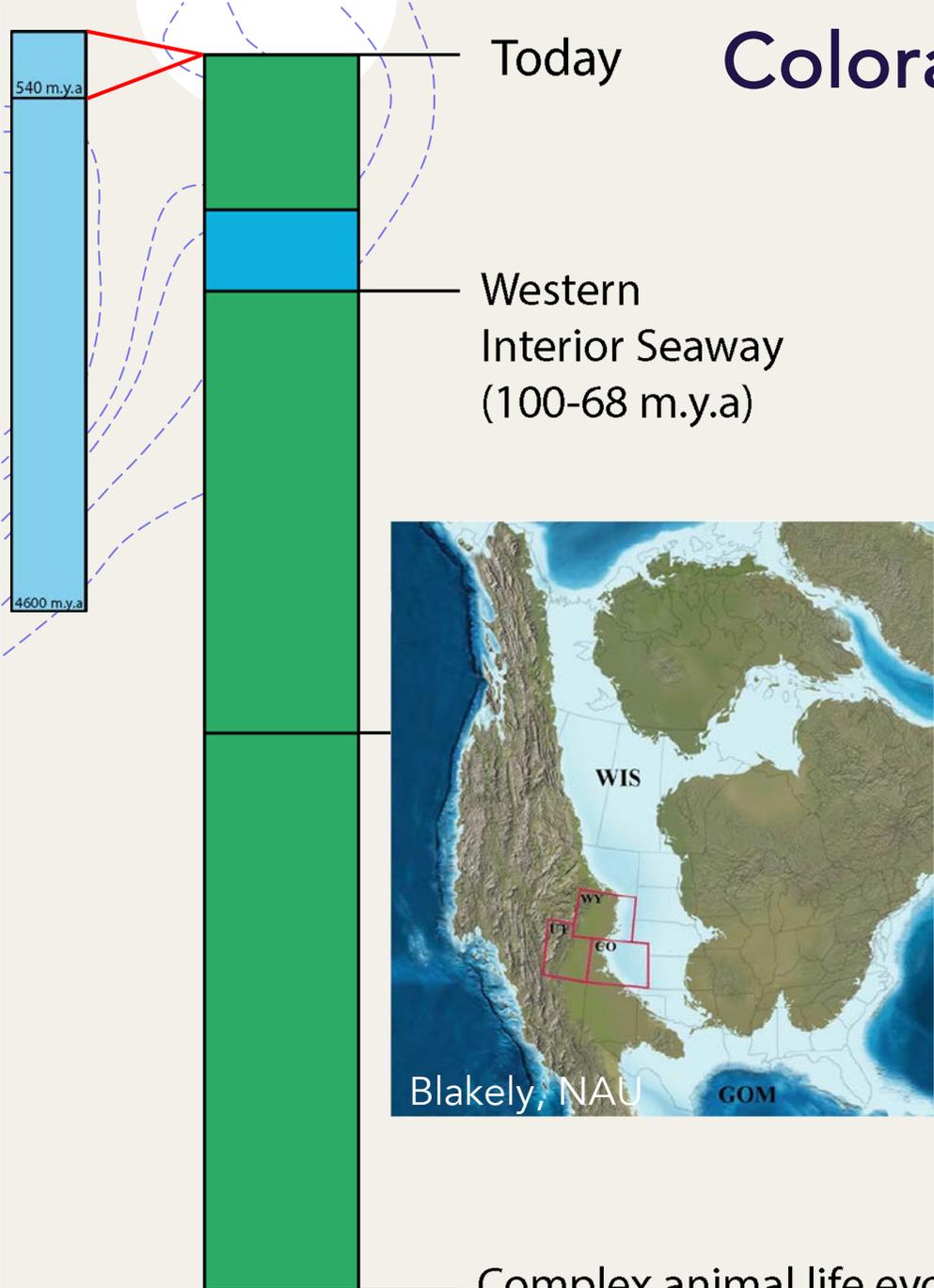
Complex animal life evolves (540 million years ago)



Colorado's Geologic History

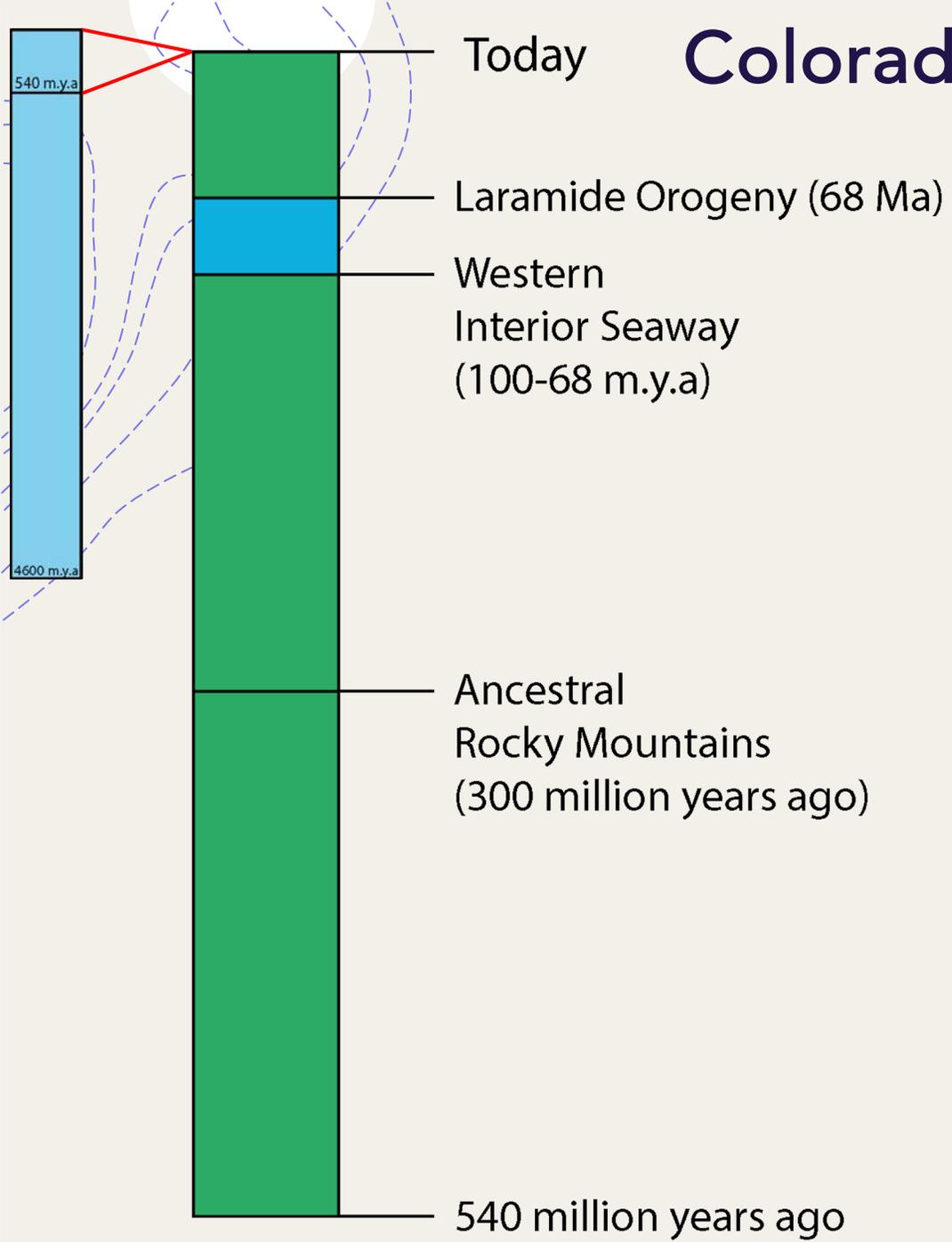


Colorado's Geologic History

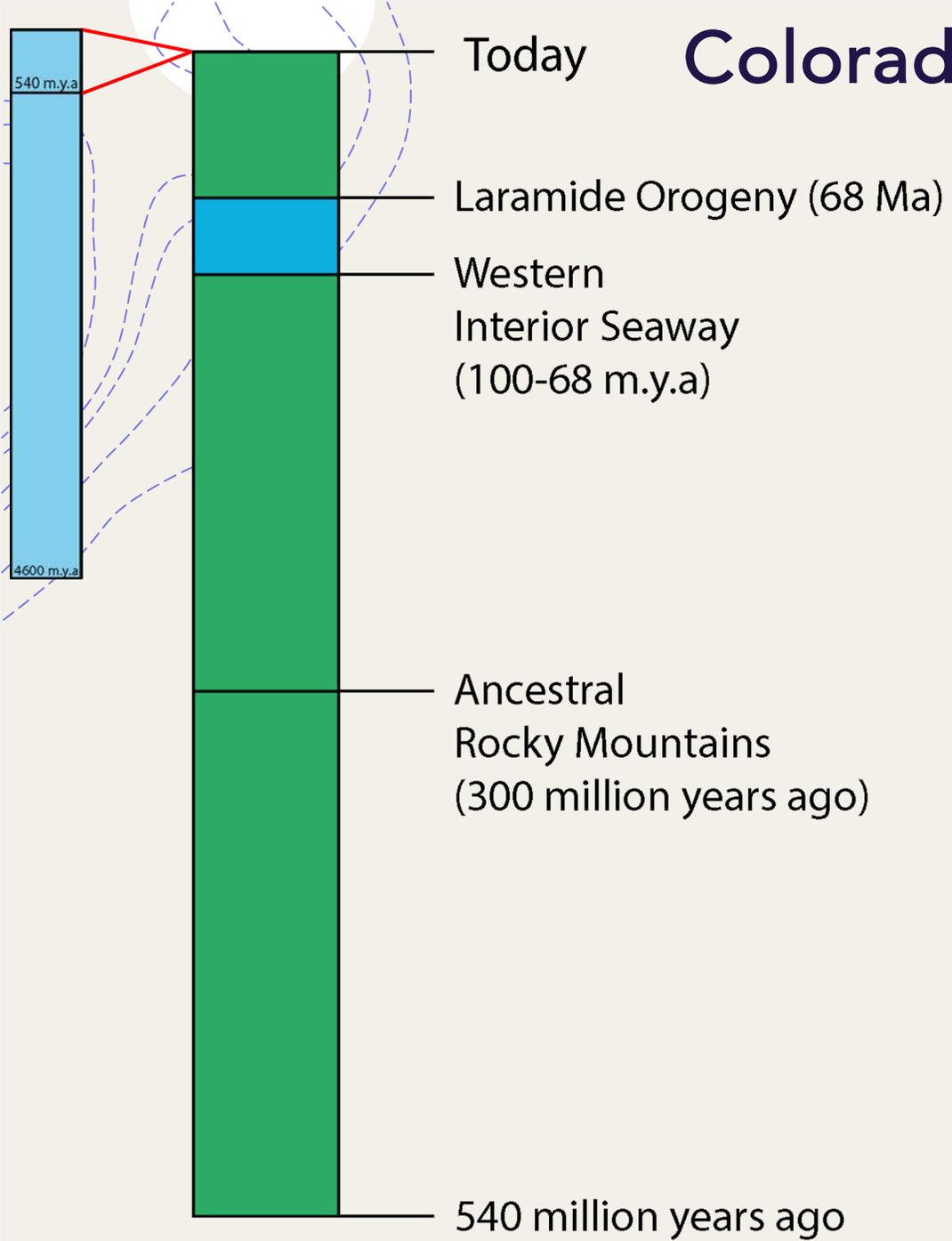


Complex animal life evolves (540 million years ago)

Colorado's Geologic History

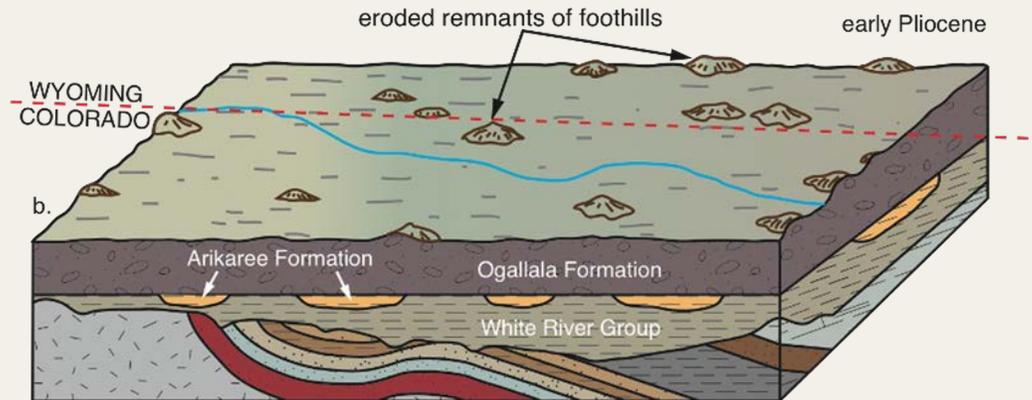
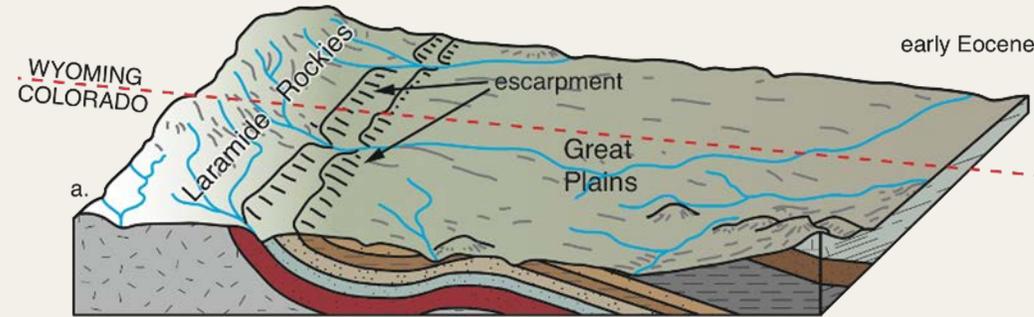
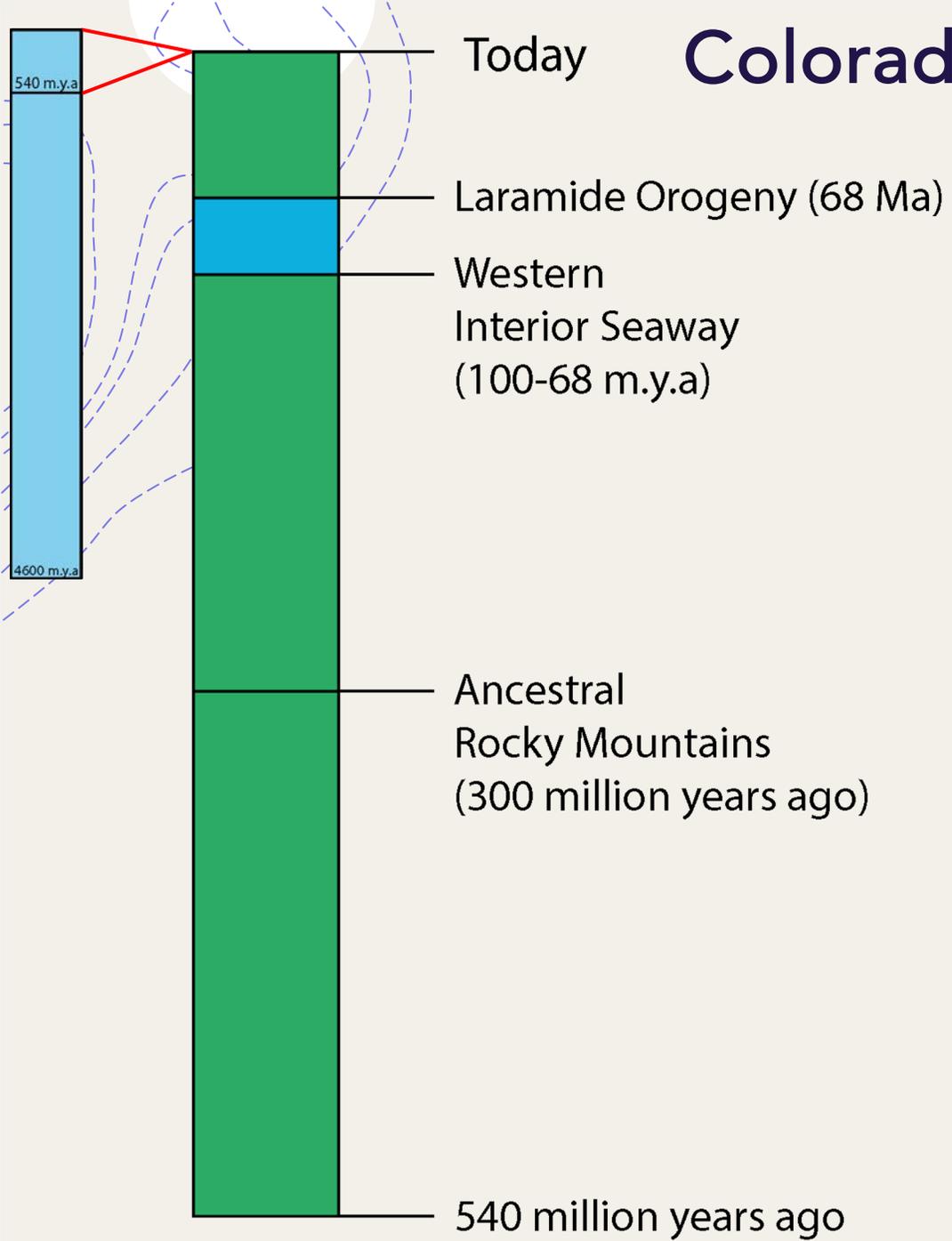


Colorado's Geologic History



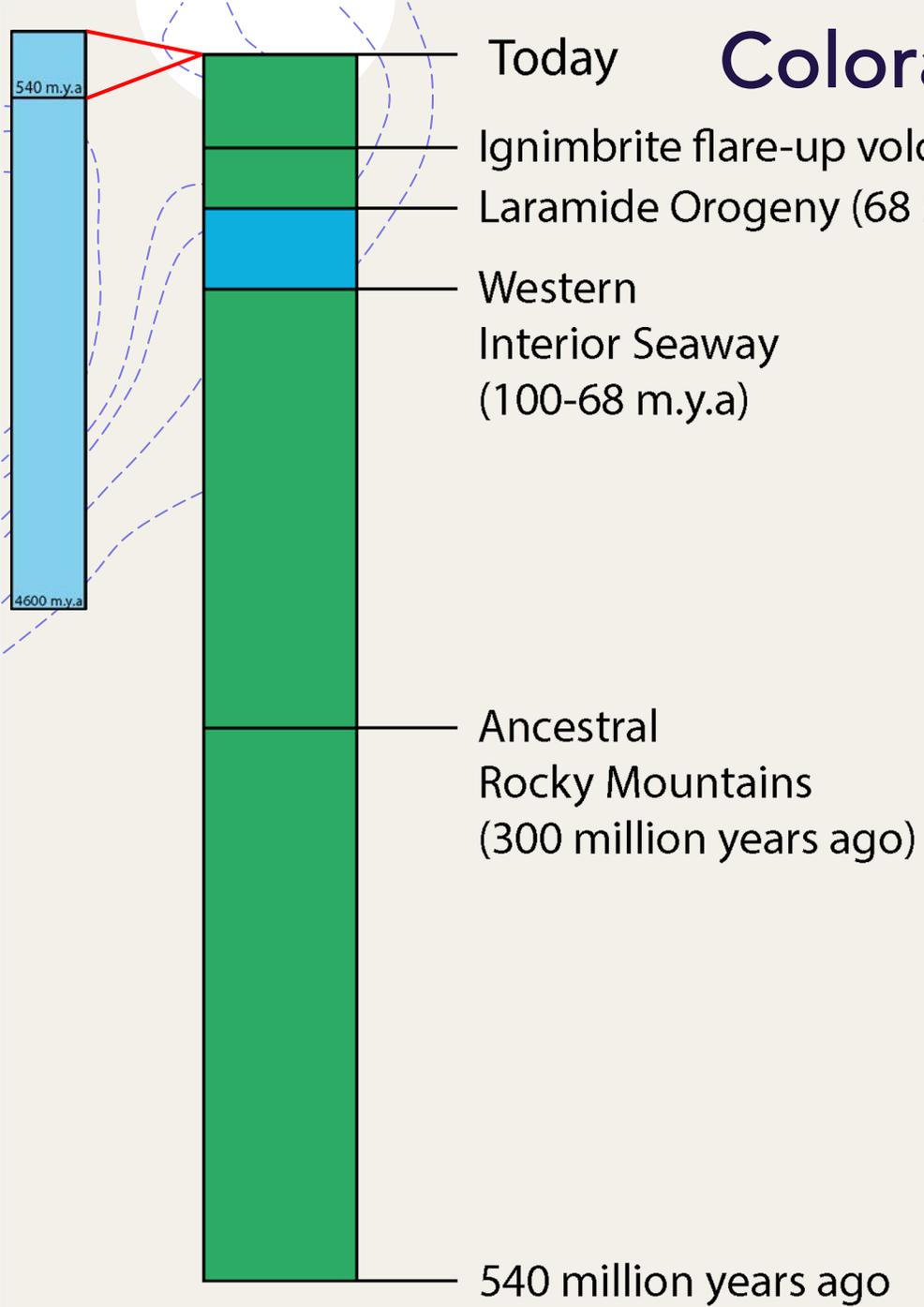
The Laramide Rocky Mountains are eroded down 37 m.y.a

Colorado's Geologic History

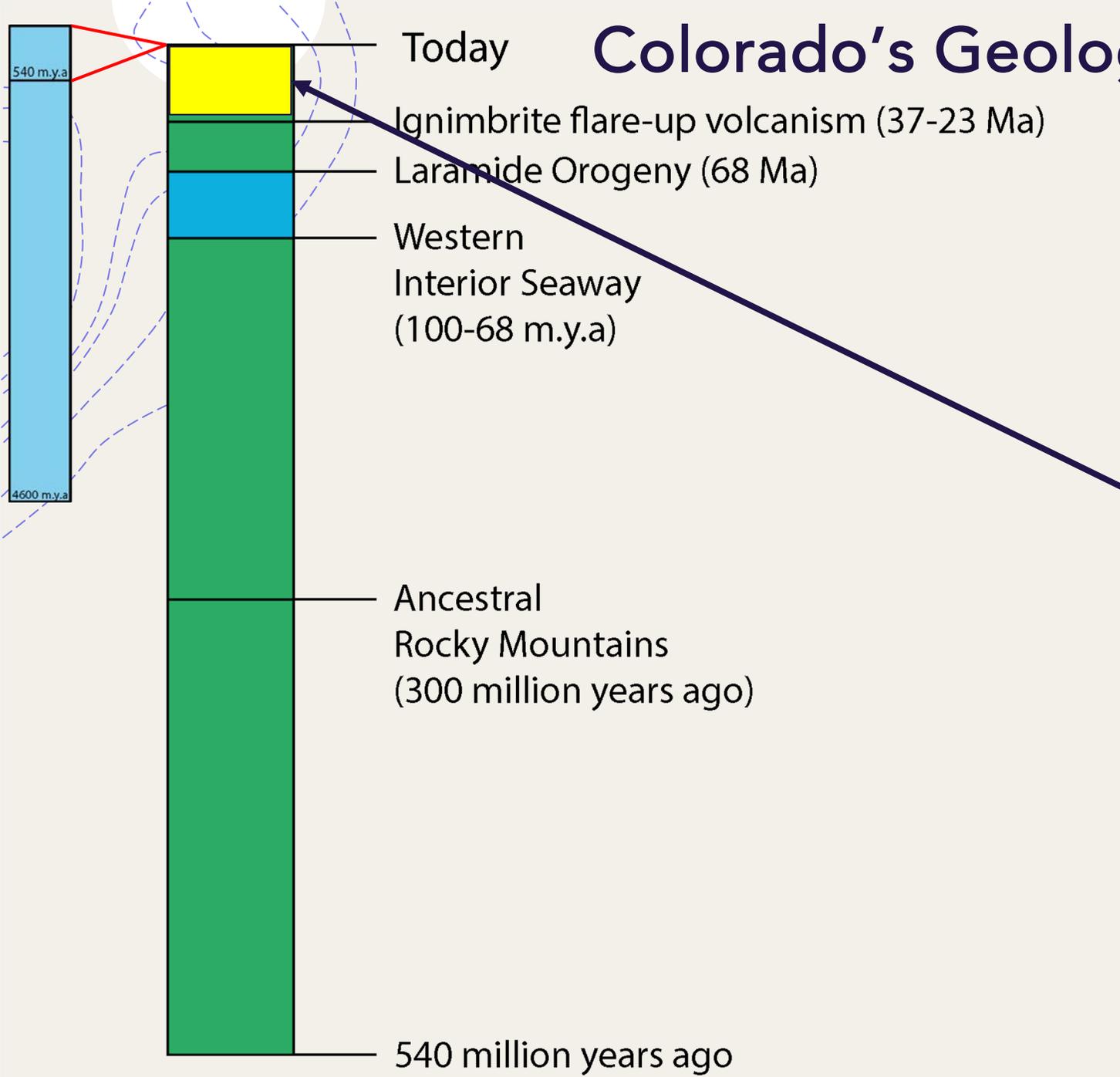


The Laramide Rocky Mountains are eroded down 37 m.y.a

Colorado's Geologic History



Colorado's Geologic History



Today's talk focuses on this time period

North America in the Oligo-Miocene (34 - 5 million years ago)



U. Nebraska



Mesohippus

HEINRICH HARDER



U. Florida

Perrisodactyls



**Wet
Mountains**

**Sangre de Cristo
Mountains**

Spanish Peaks

Saguache

Crestone

Westcliffe

Fowler

Colorado City

Center

Walsenburg

Monte Vista

La Veta

Alamosa

Fort Garland

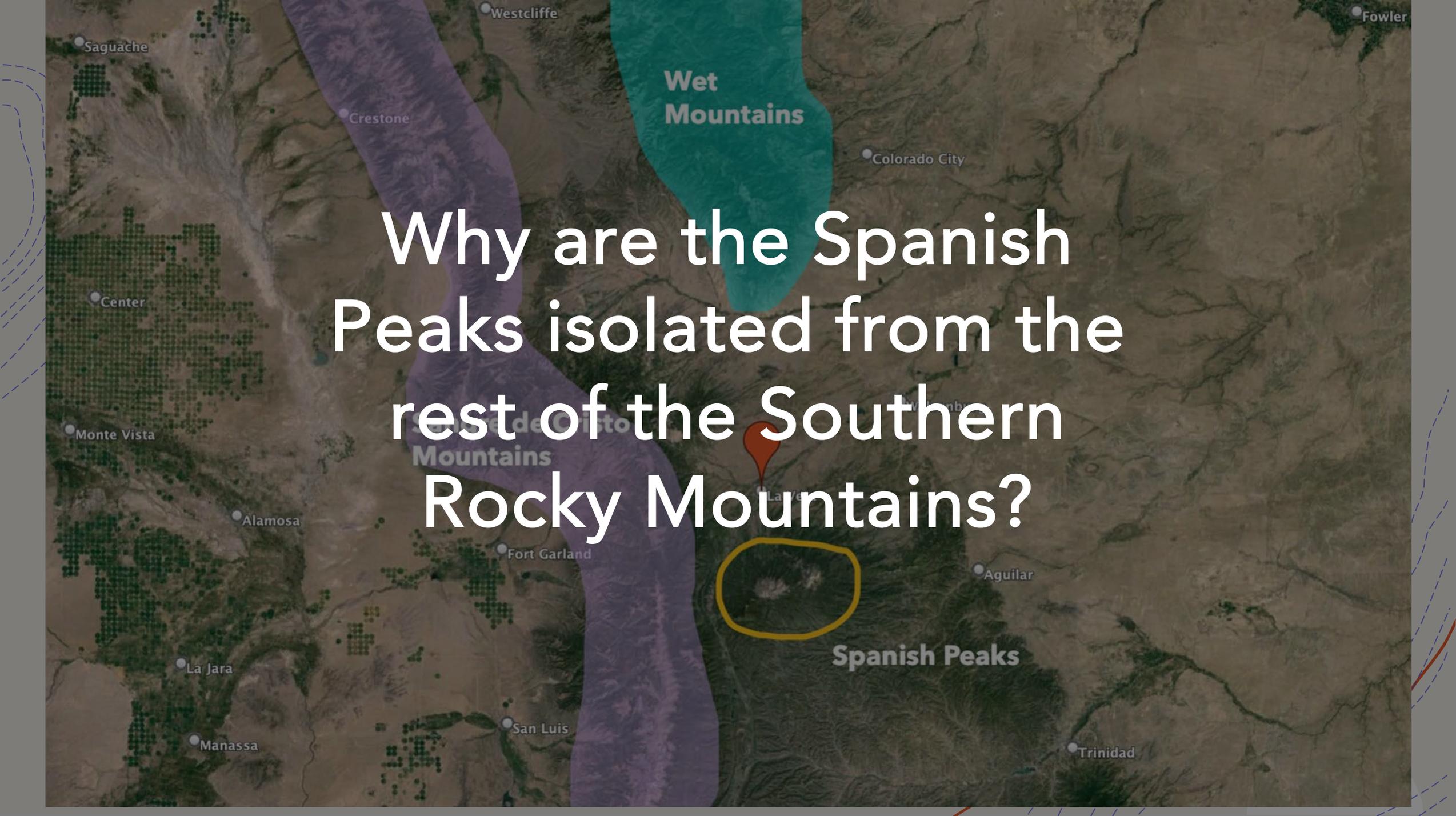
Aguilar

La Jara

Manassa

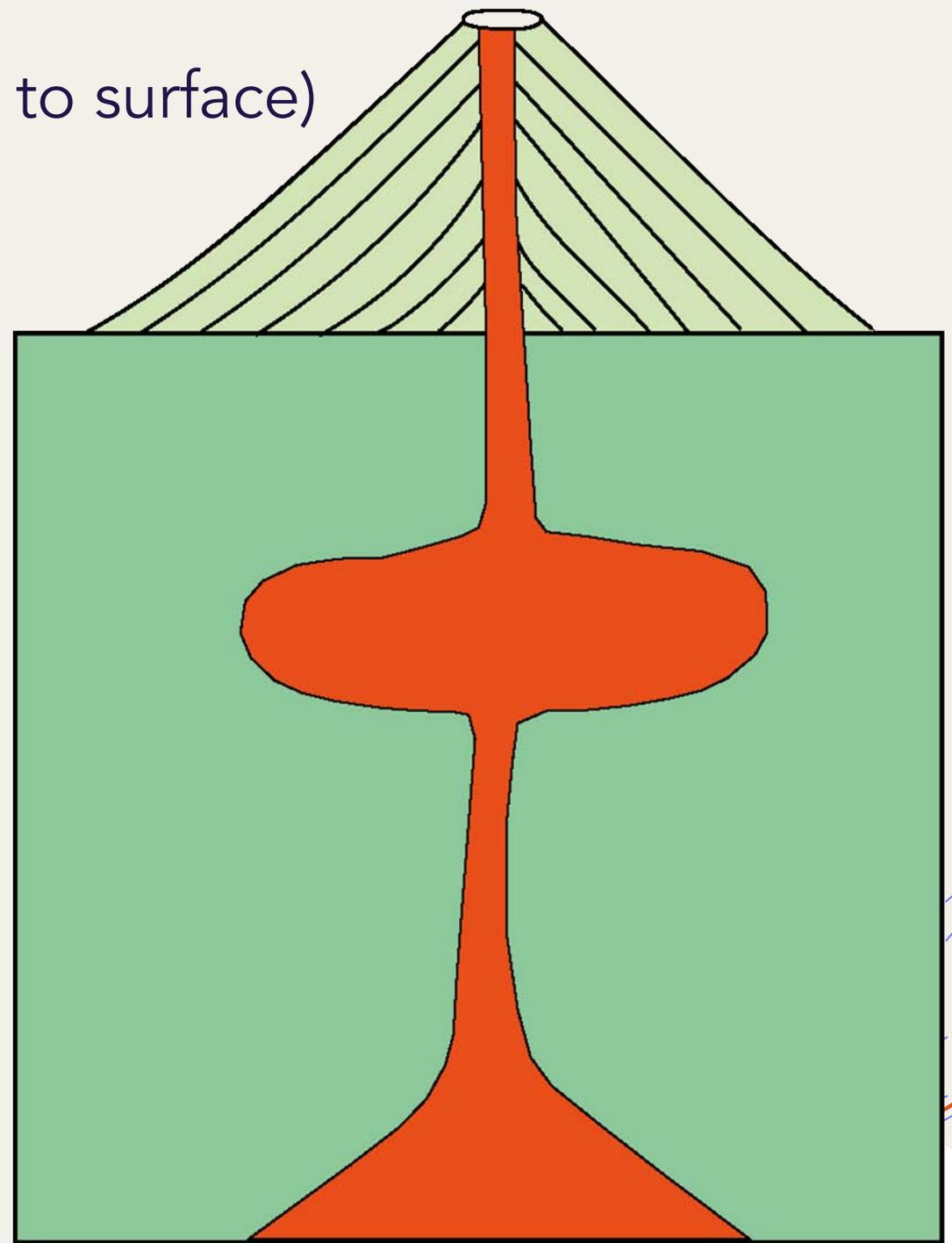
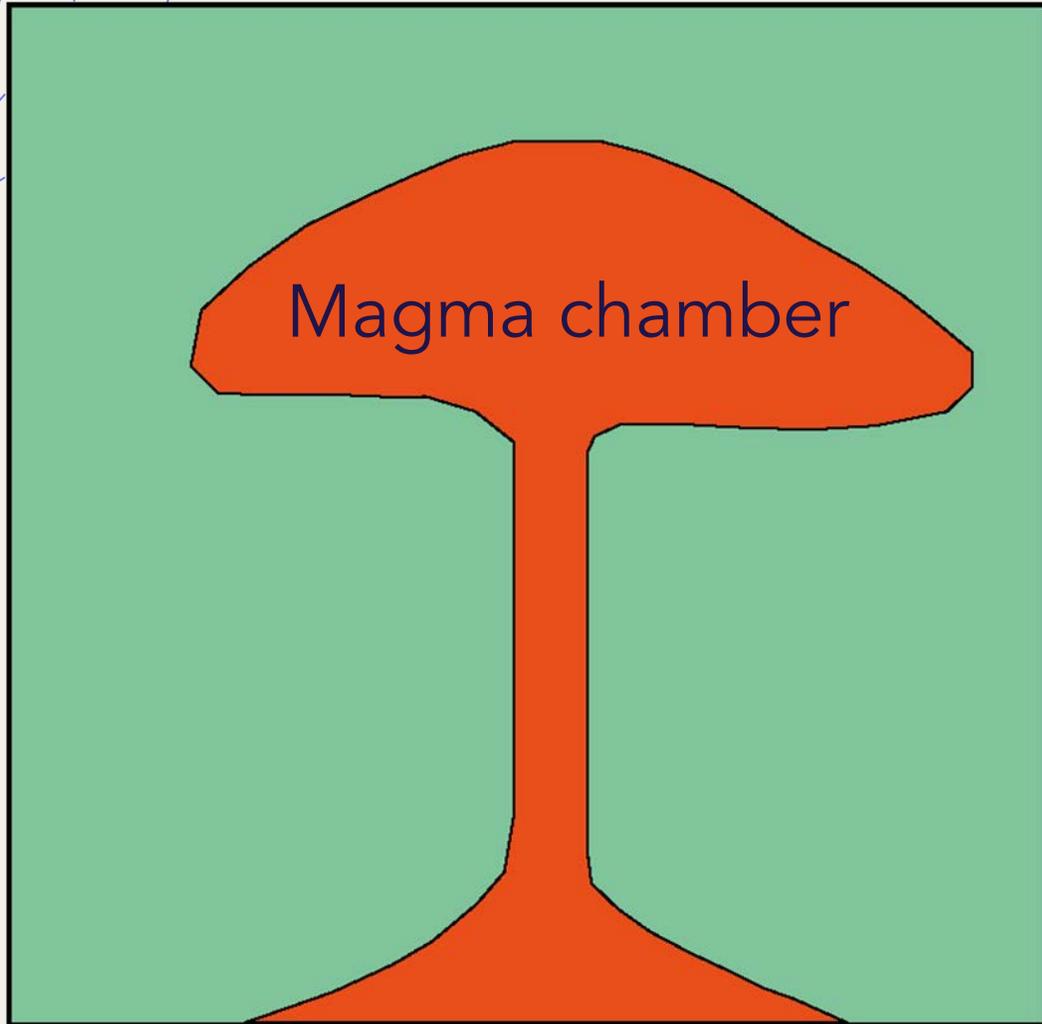
San Luis

Trinidad

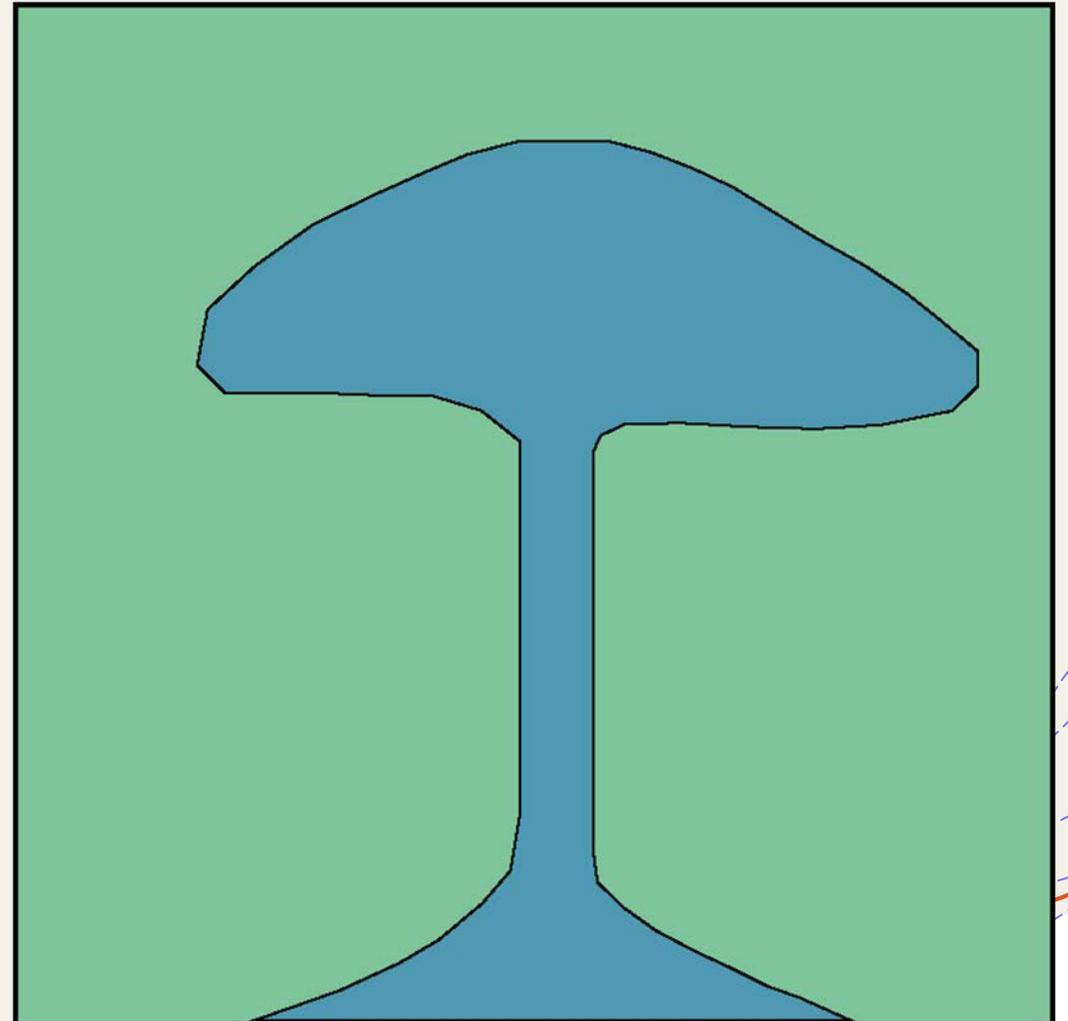
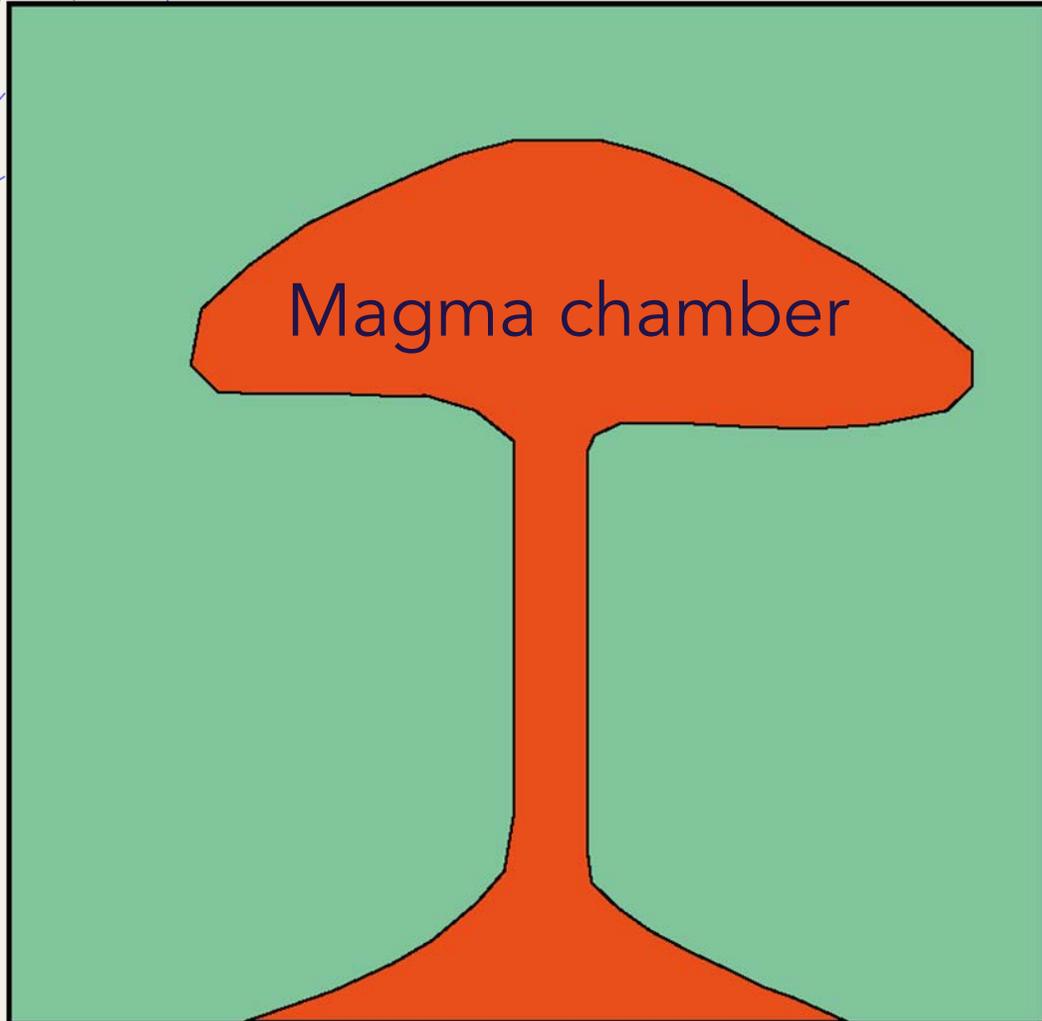
A topographic map of the Southern Rocky Mountains region in Colorado. The map features several mountain ranges highlighted with semi-transparent colors: the Wet Mountains in teal, the Spanish Peaks in yellow, and the Sangre de Cristo Mountains in purple. A red location pin is placed on a peak within the Spanish Peaks range, which is also circled in yellow. Numerous towns and cities are labeled across the region, including Saguache, Crestone, Westcliffe, Colorado City, Center, Monte Vista, Alamosa, Fort Garland, La Jara, Manassa, San Luis, Aguilar, and Trinidad. The text 'Why are the Spanish Peaks isolated from the rest of the Southern Rocky Mountains?' is overlaid in large white font in the center of the map.

Why are the Spanish Peaks isolated from the rest of the Southern Rocky Mountains?

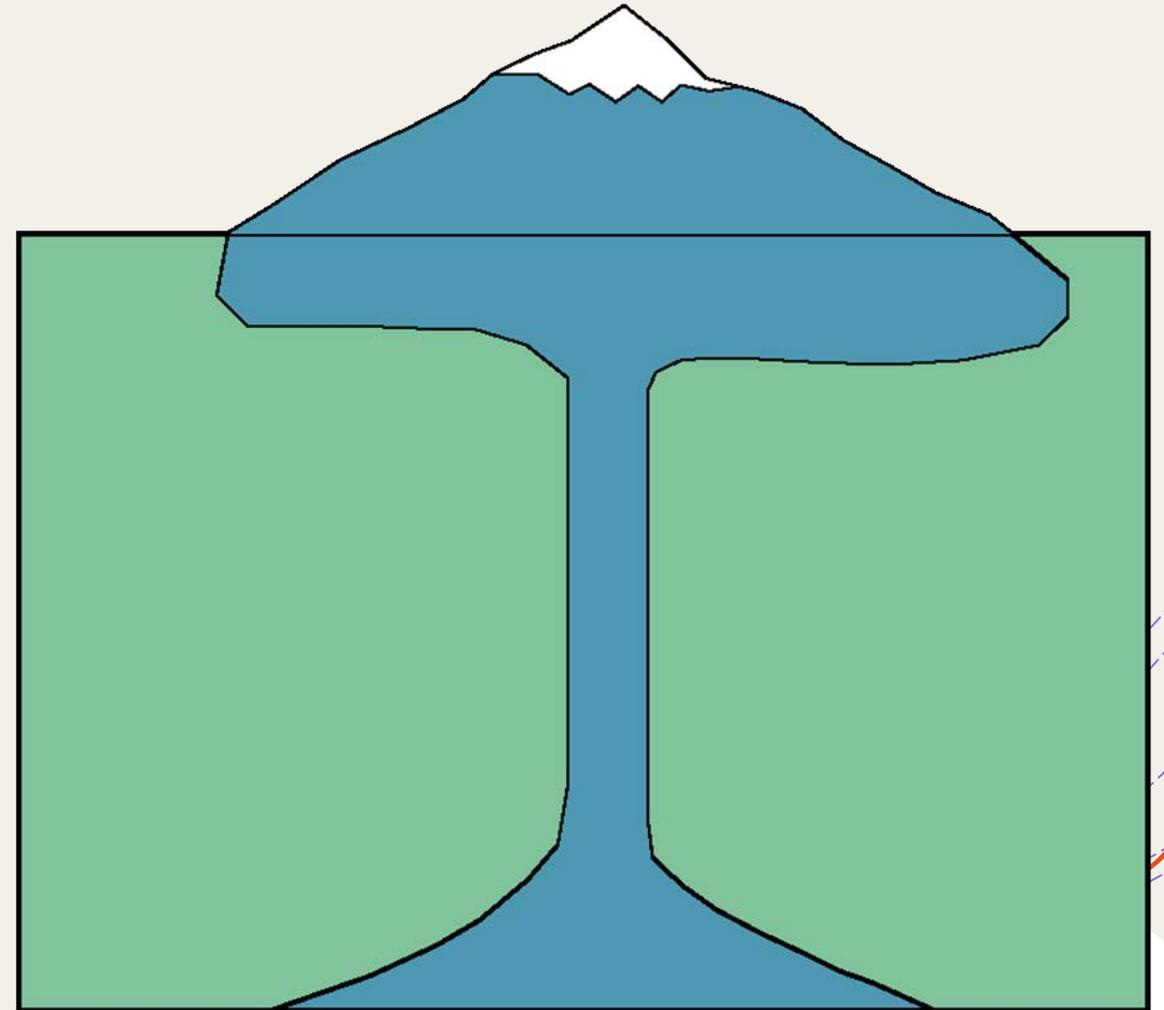
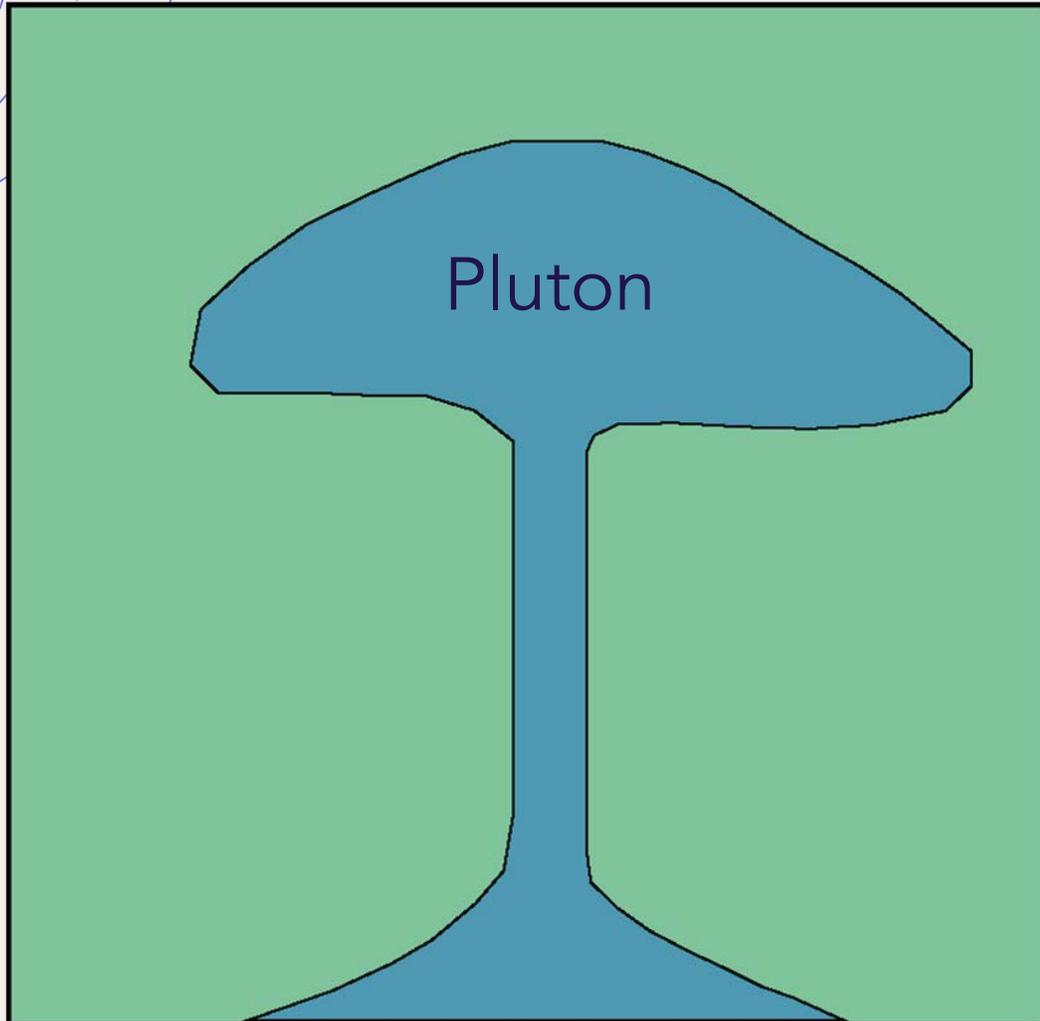
Volcano (extrudes to surface)



Pluton (solidifies below surface)

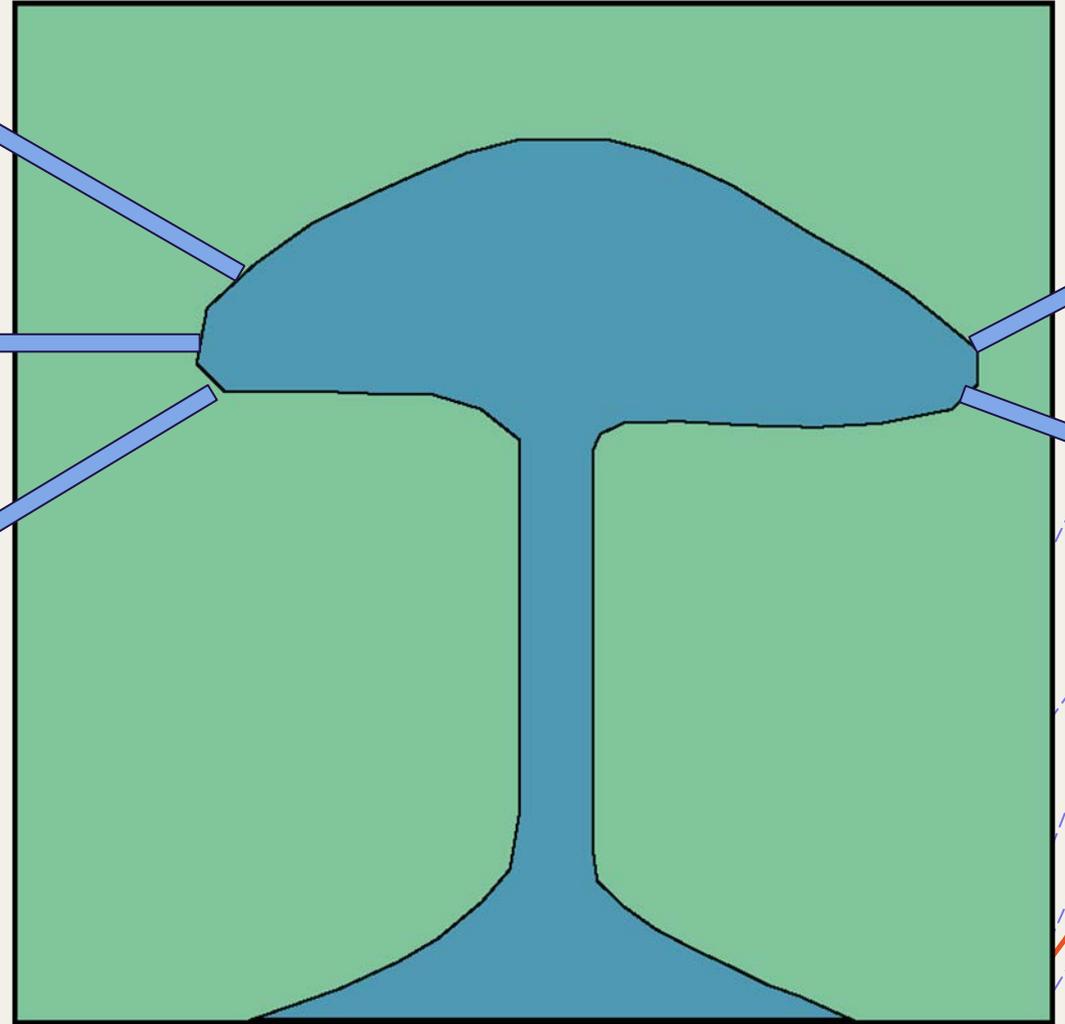
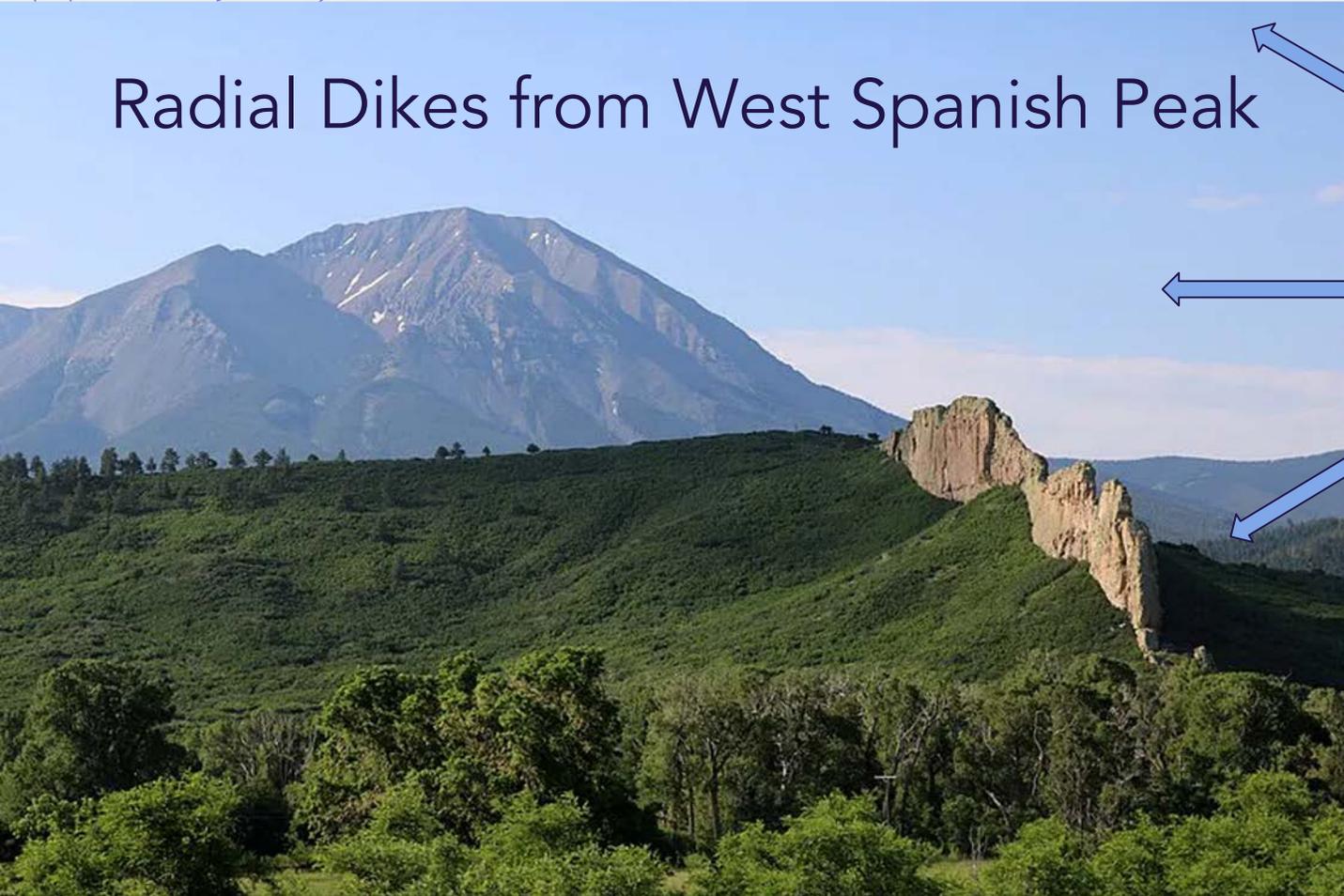


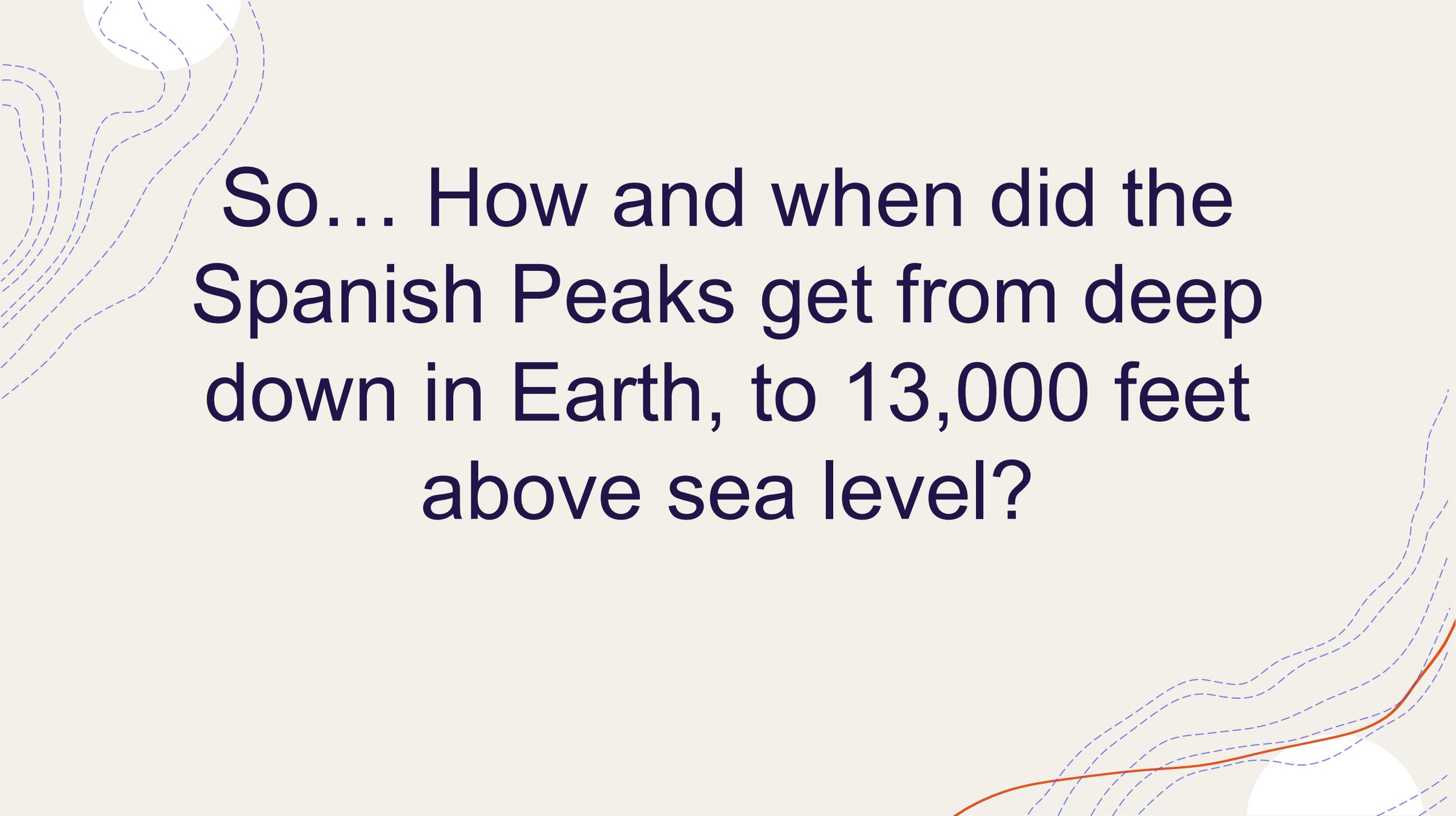
Erosion of less resistant rock
leaves pluton standing
above all else





Radial Dikes from West Spanish Peak



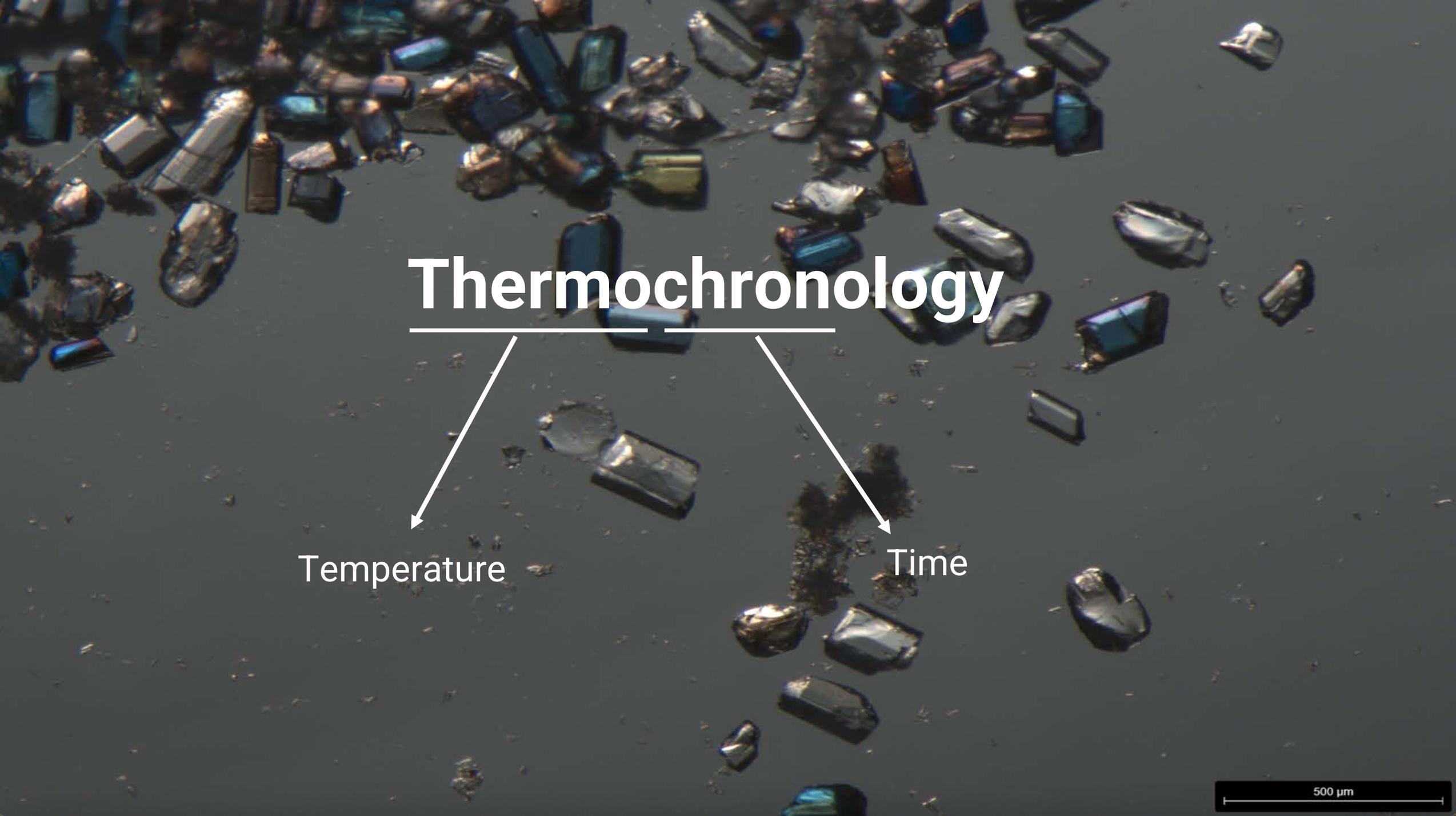


So... How and when did the Spanish Peaks get from deep down in Earth, to 13,000 feet above sea level?



Studying the evolution of landscapes

Thermochronology

A microscopic image of numerous zircon crystals, which are small, dark, and angular. The crystals are scattered across the frame, with a higher concentration in the upper left. A white horizontal line is drawn across the middle of the image, with the word "Thermochronology" written in white text above it. Two white arrows point downwards from the ends of this line to the words "Temperature" and "Time". In the bottom right corner, there is a black scale bar with the text "500 μm" in white.

Temperature

Time

500 μm

Most rocks have radioactive atoms



Autunite (visible light)

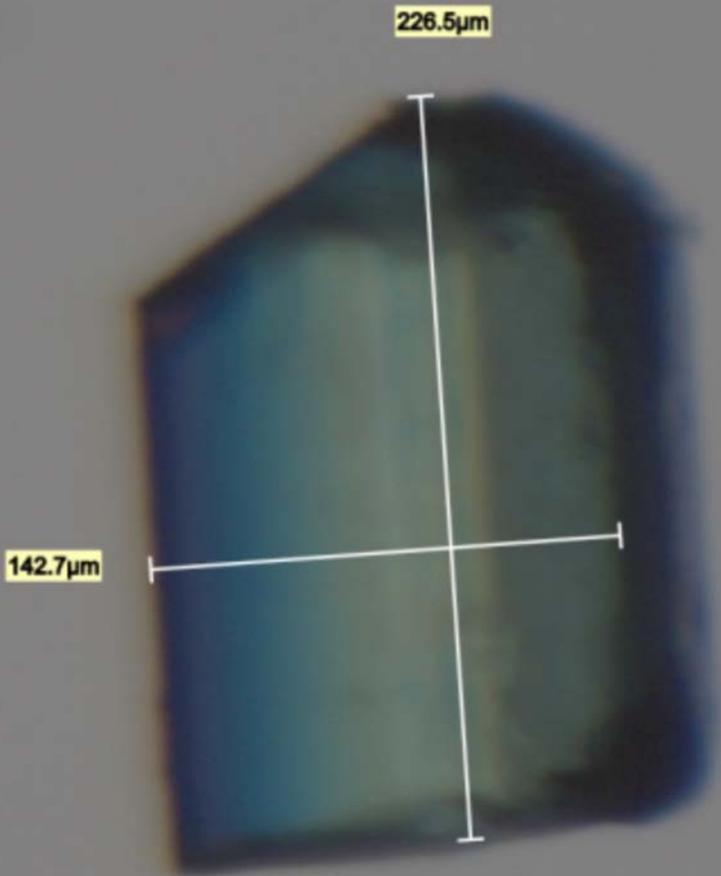


Autunite (UV light)

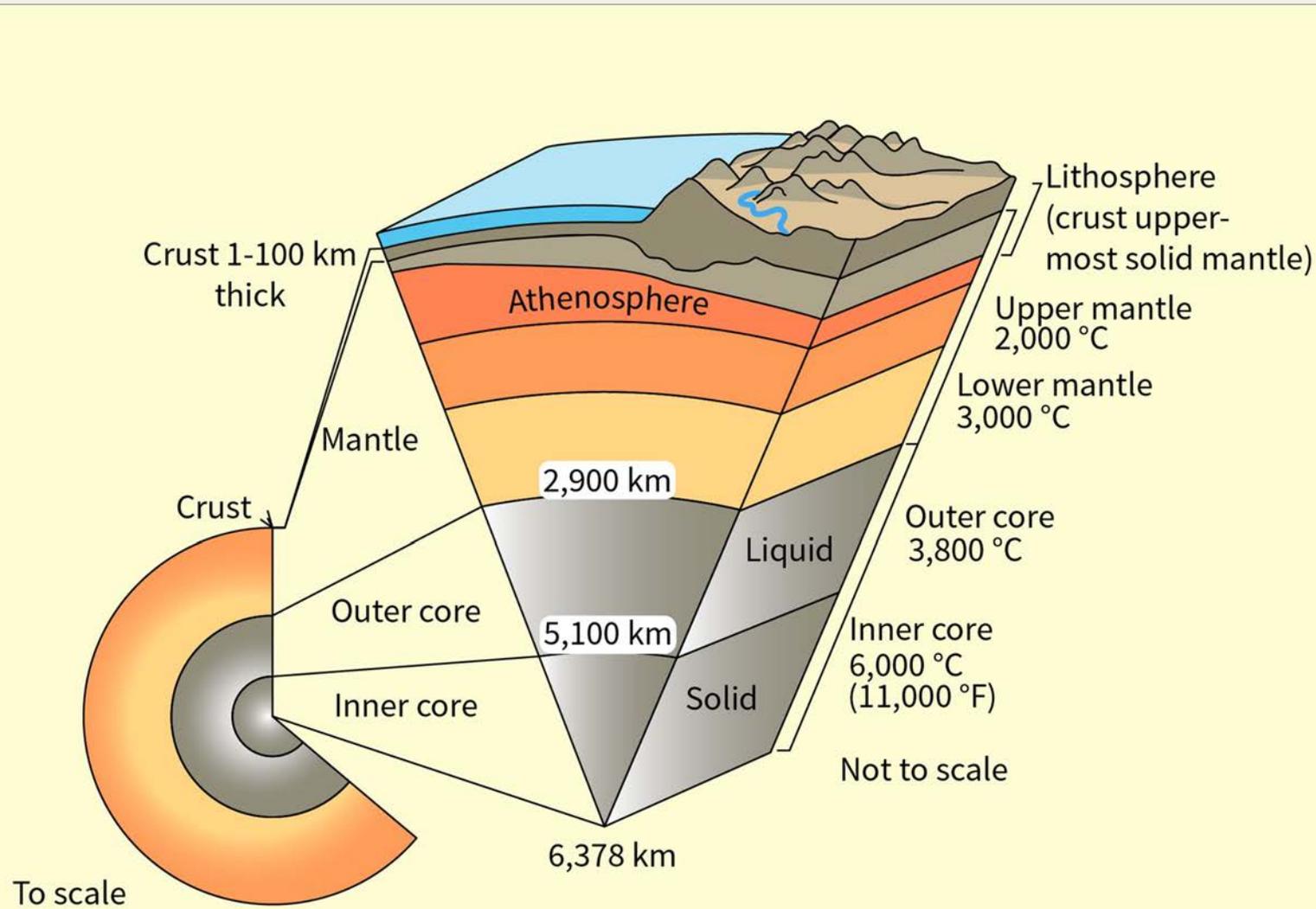
electromrk



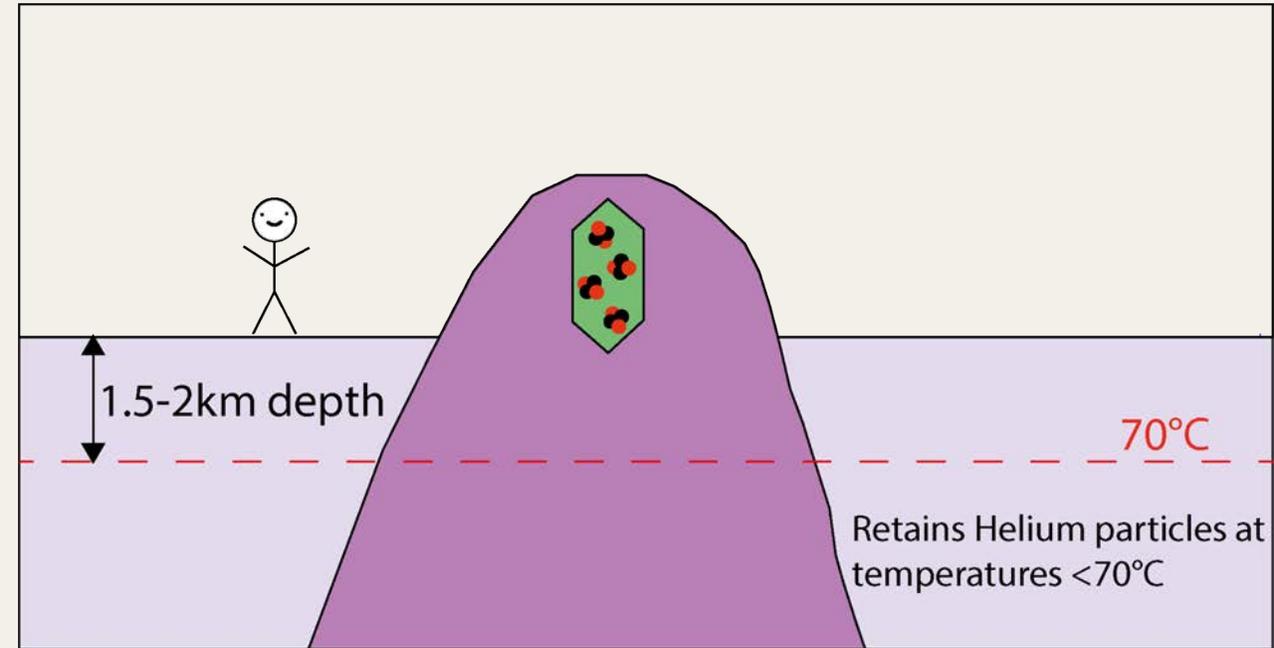
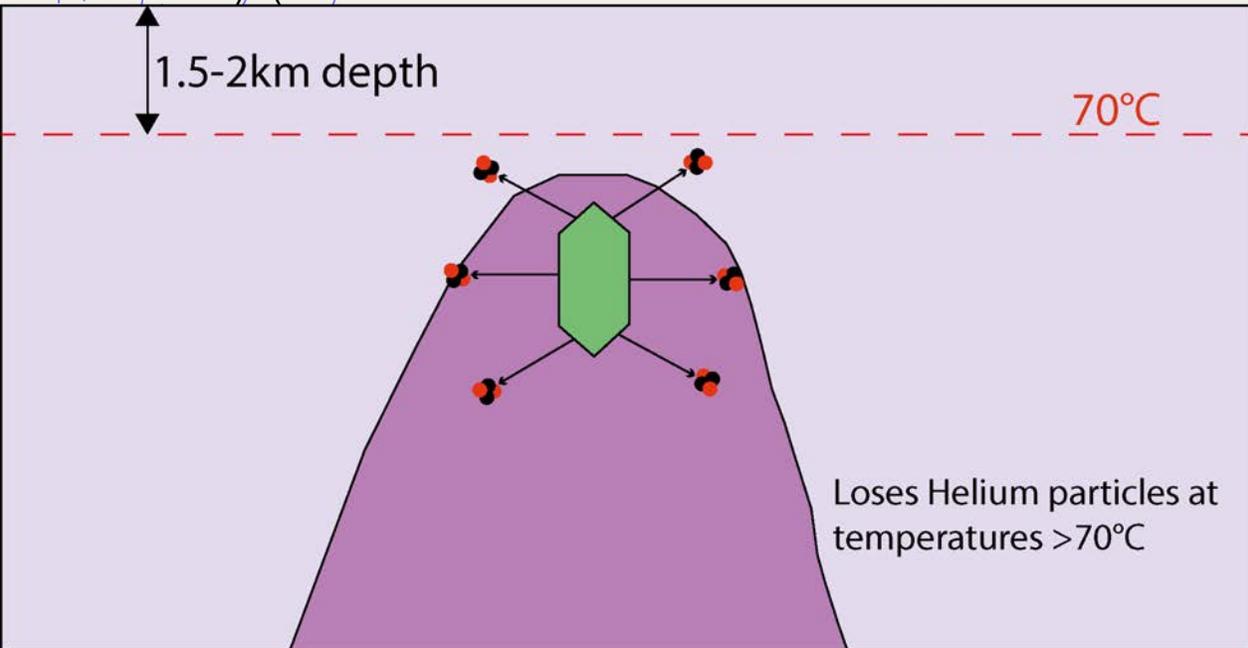
Apatite: A mineral clock and thermometer



Earth gets HOT the deeper down you go



Tells us WHEN a rock cools to near-surface conditions



70°C = 160°F

From rock to data



Measures Helium



Measures Uranium and Thorium



Thermochronology in the Spanish Peaks



Muleshoe

Fir

La Veta

SK20-1

CS13-8

CS13-6

CS13-7

LA19-9 - ESP

Cuchara

Walsenburg

Lynn

Aguilar

Gulnare

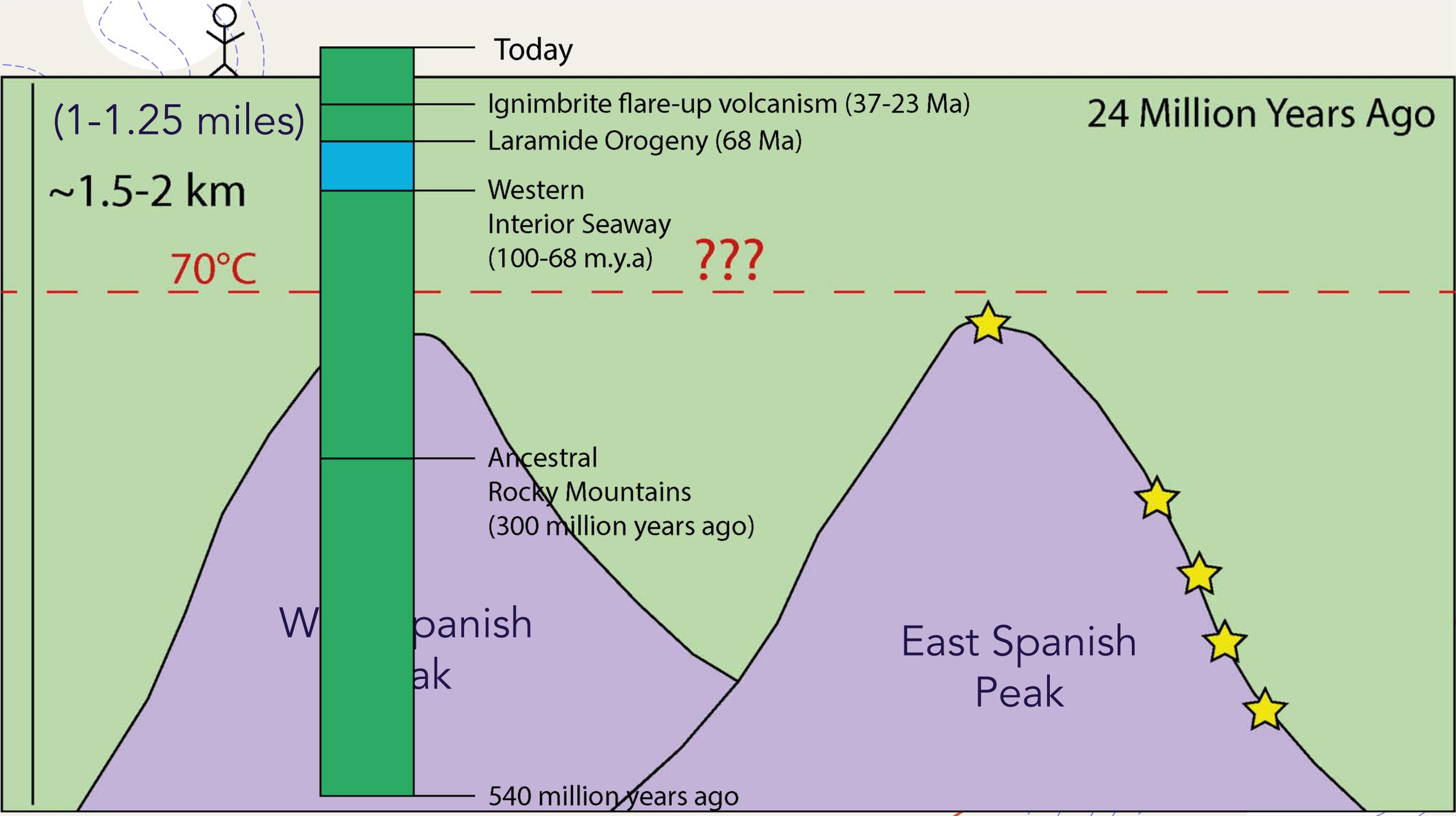
12.6 km

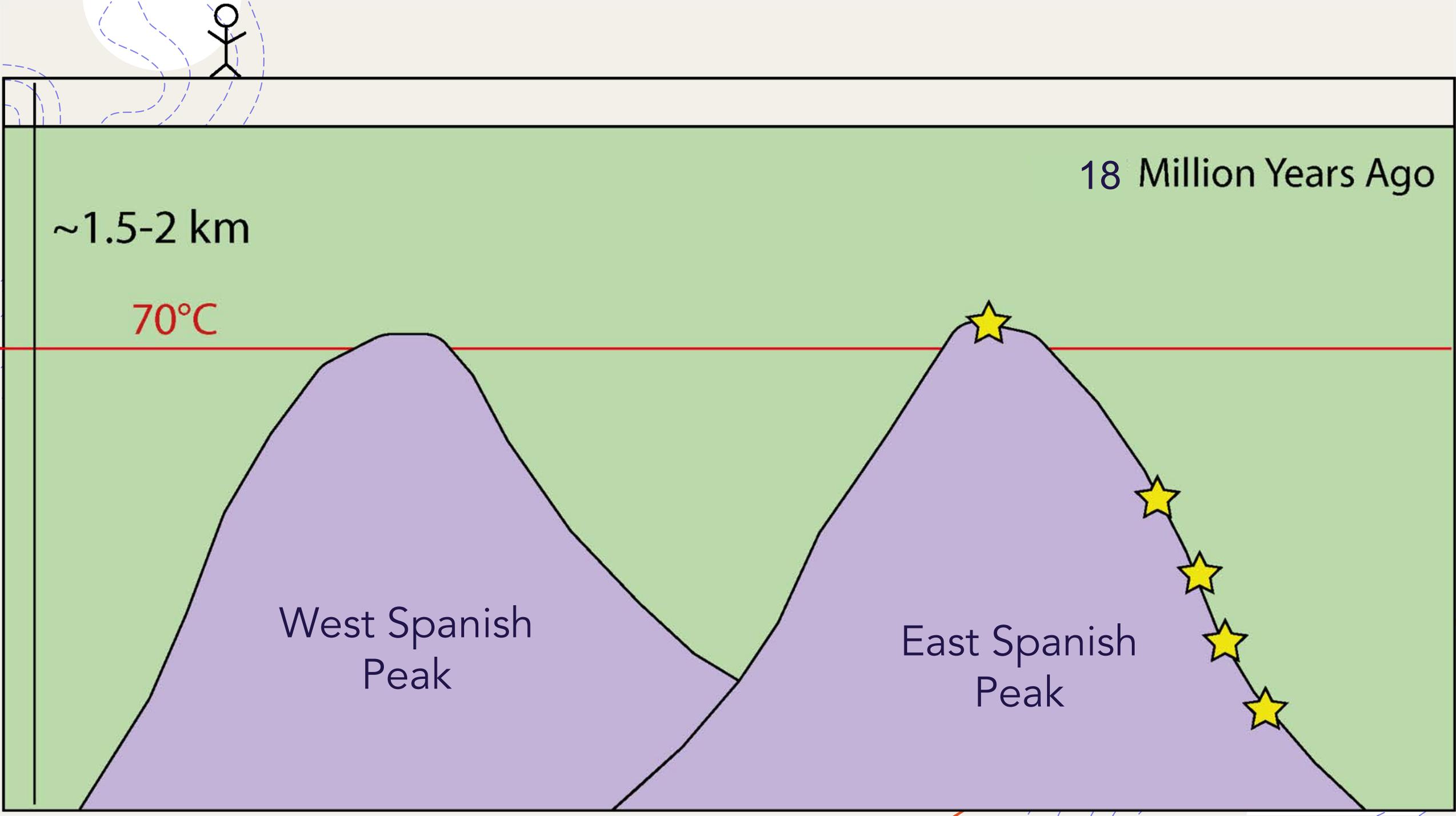
Trinchera Peak

Image © 2024 Airbus

Google Earth

Imagery Date: 6/2/2024 lat 37.426211° lon -104.875714° elev 0 m eye alt 54.38 km





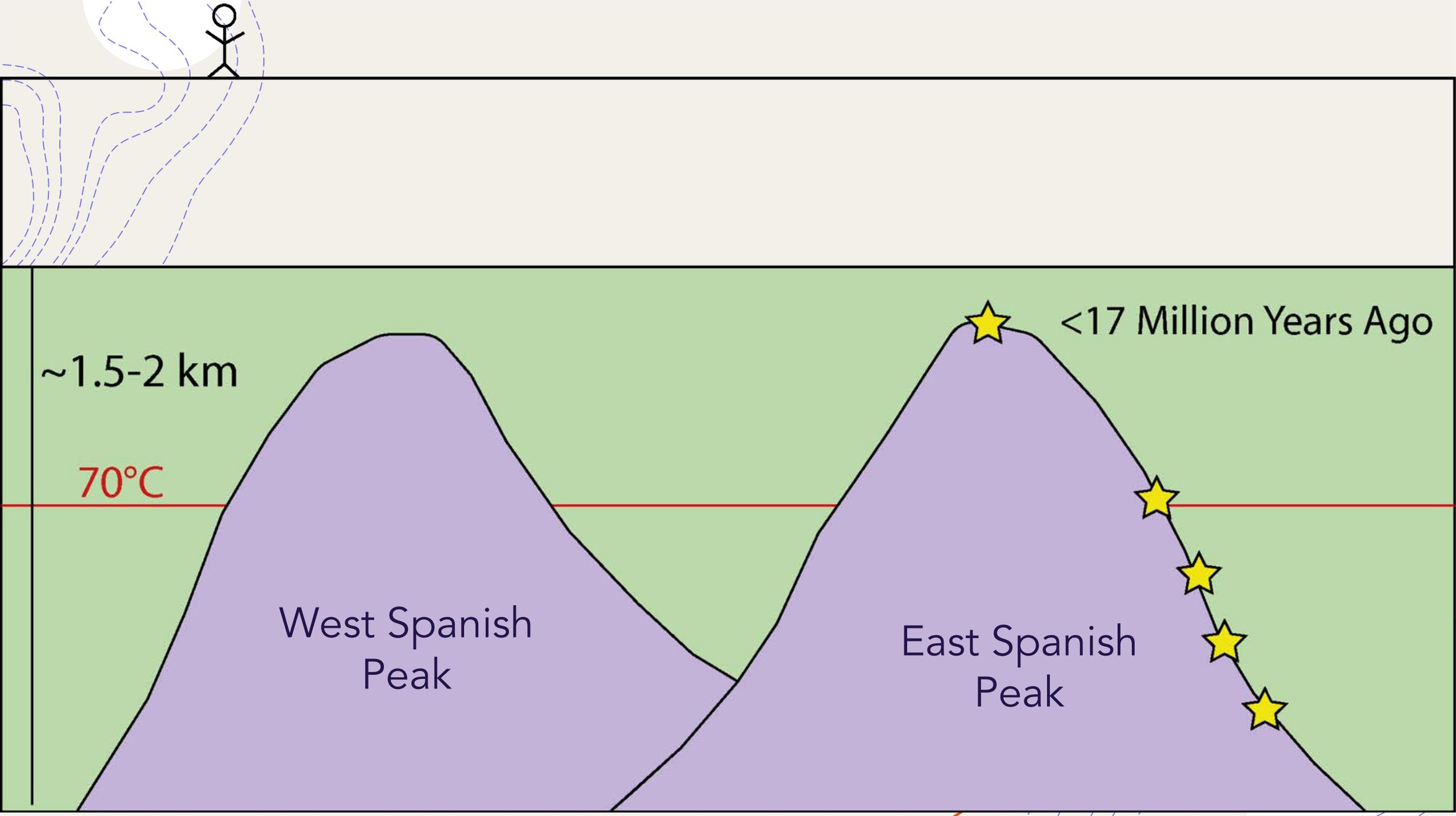
18 Million Years Ago

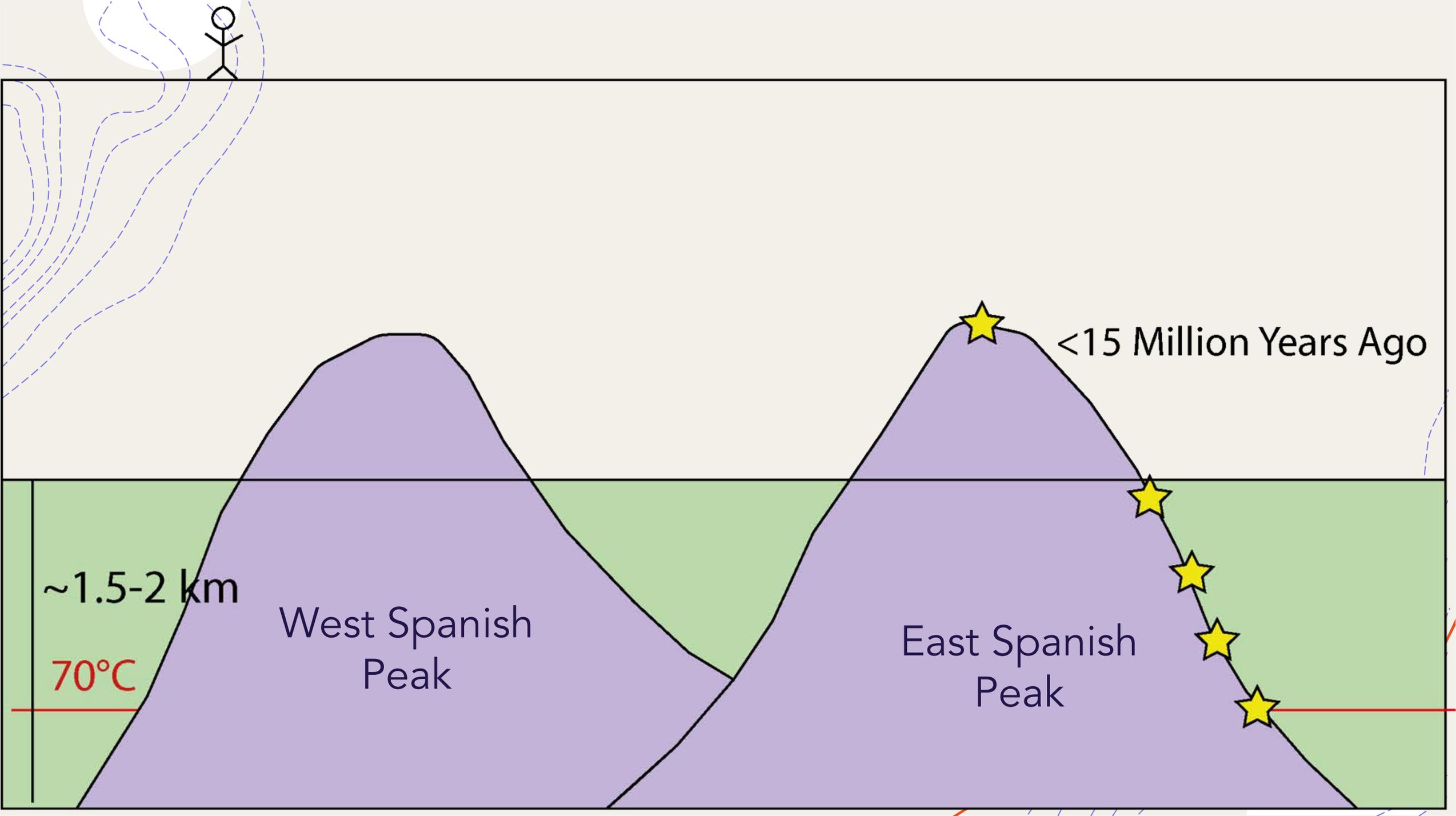
~1.5-2 km

70°C

West Spanish Peak

East Spanish Peak





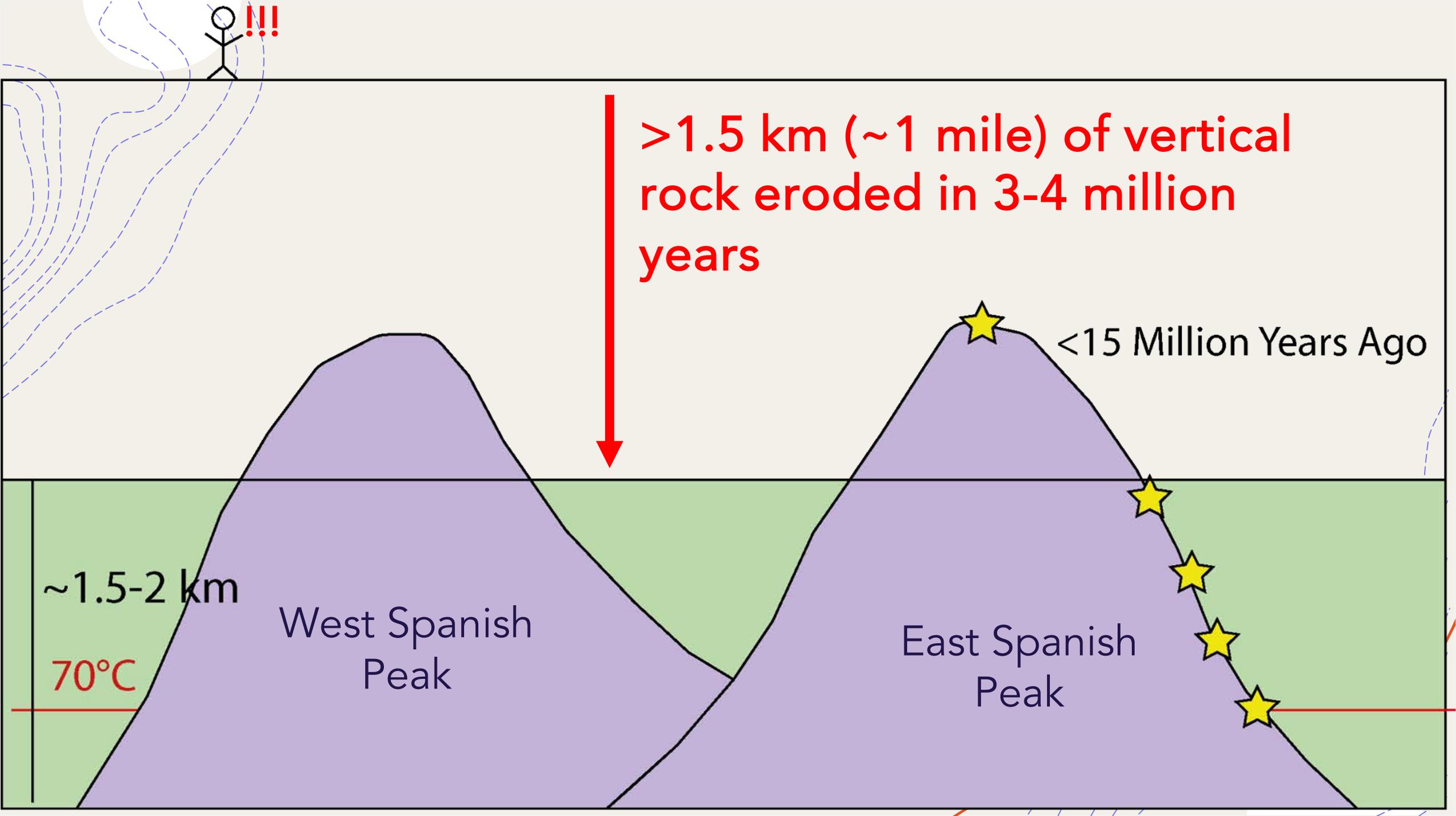
$\sim 1.5-2$ km

70°C

West Spanish Peak

East Spanish Peak

<15 Million Years Ago



**>1.5 km (~1 mile) of vertical
rock eroded in 3-4 million
years**

<15 Million Years Ago

~1.5-2 km

70°C

**West Spanish
Peak**

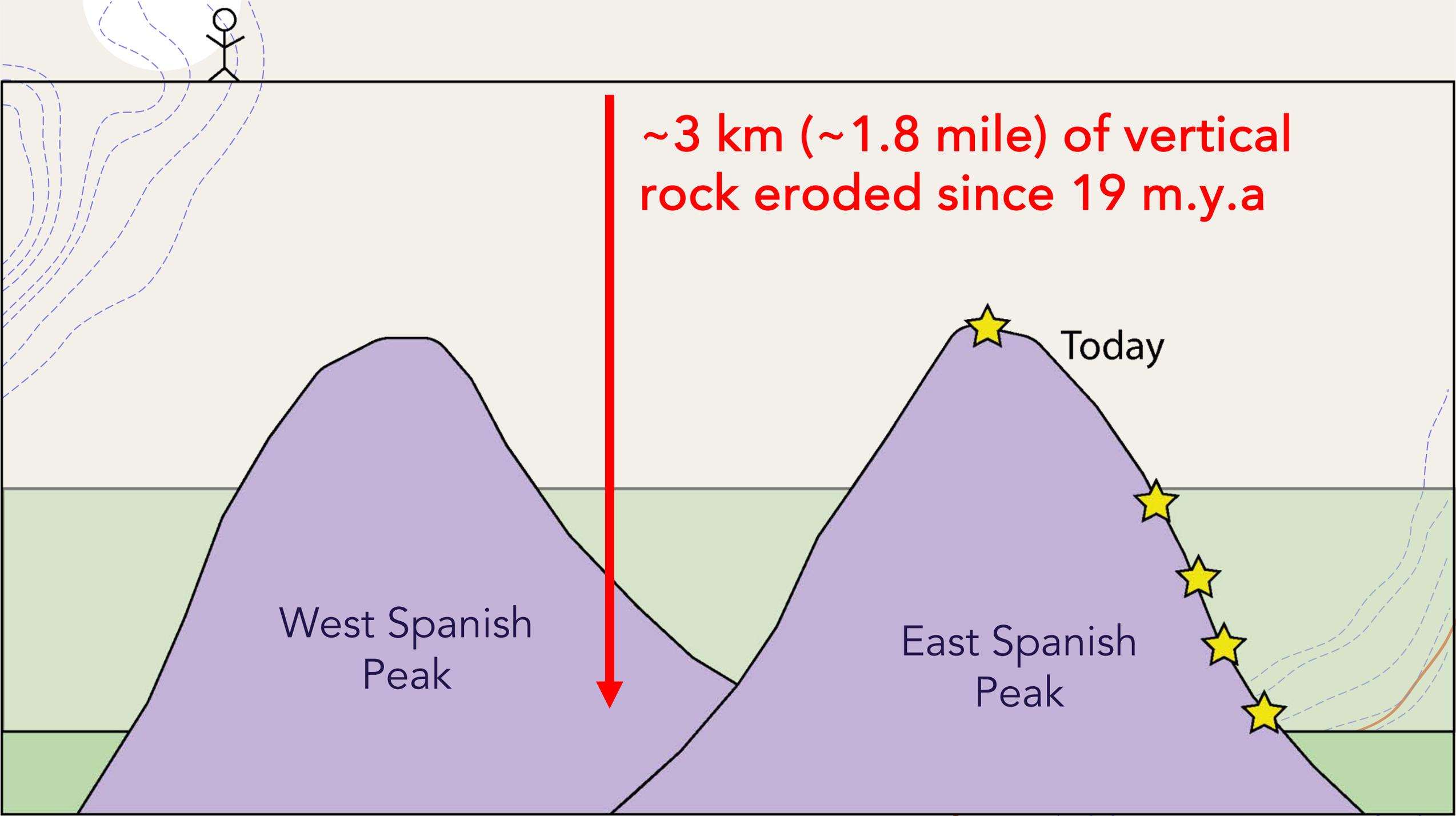
**East Spanish
Peak**

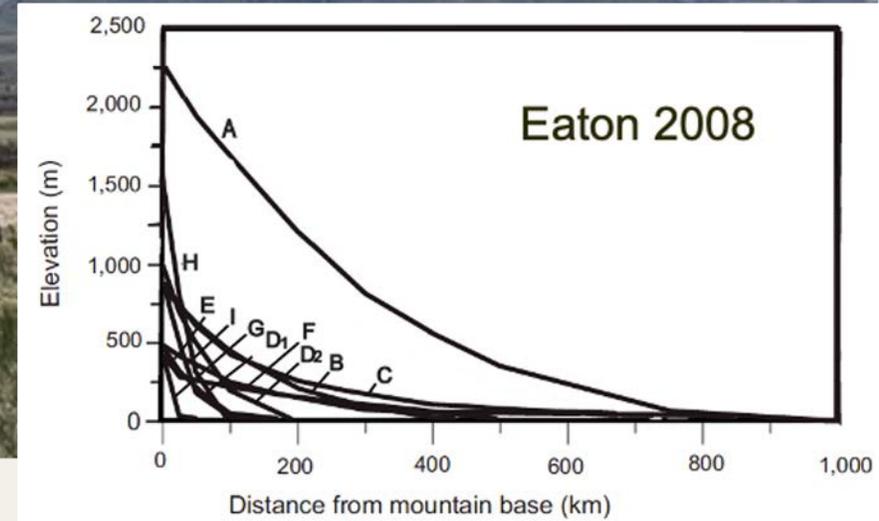
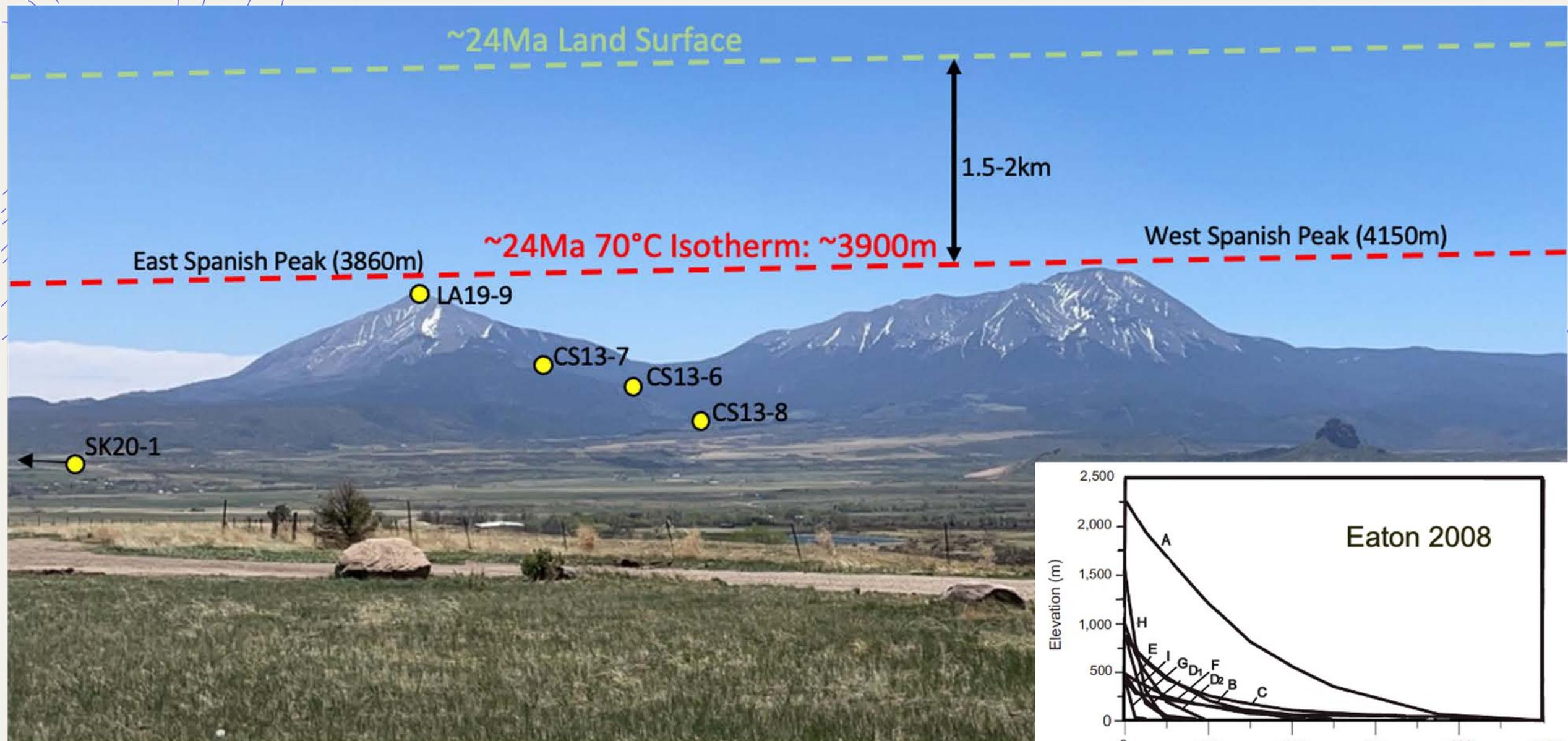
**~3 km (~1.8 mile) of vertical
rock eroded since 19 m.y.a**

West Spanish
Peak

East Spanish
Peak

Today







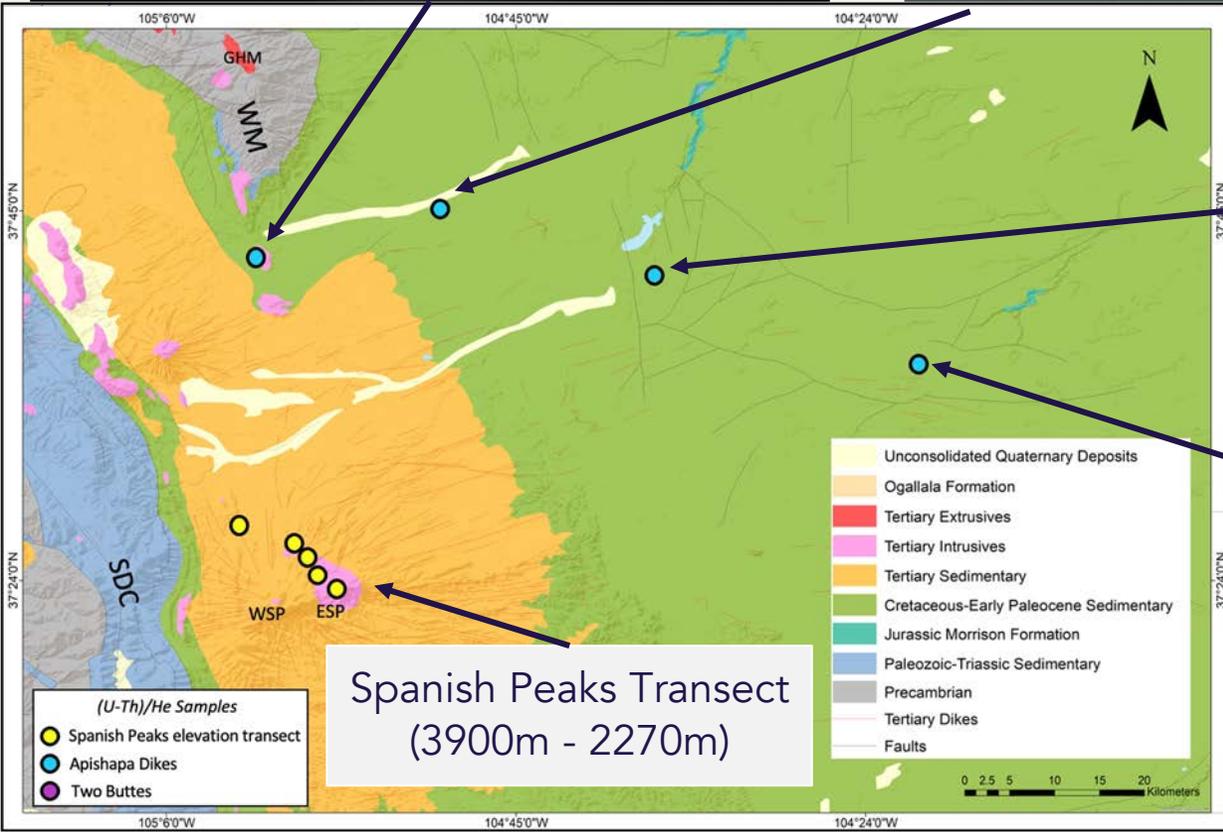
Looking out East: How widespread is the erosional episode?

Apishapa Dikes and Two Buttes

Little Black Hills (2050m)



Huerfano Butte (1820m)



Cucharas Reservoir Dike (1800m)

Mica Butte (1730m)



Two Buttes (1320m)



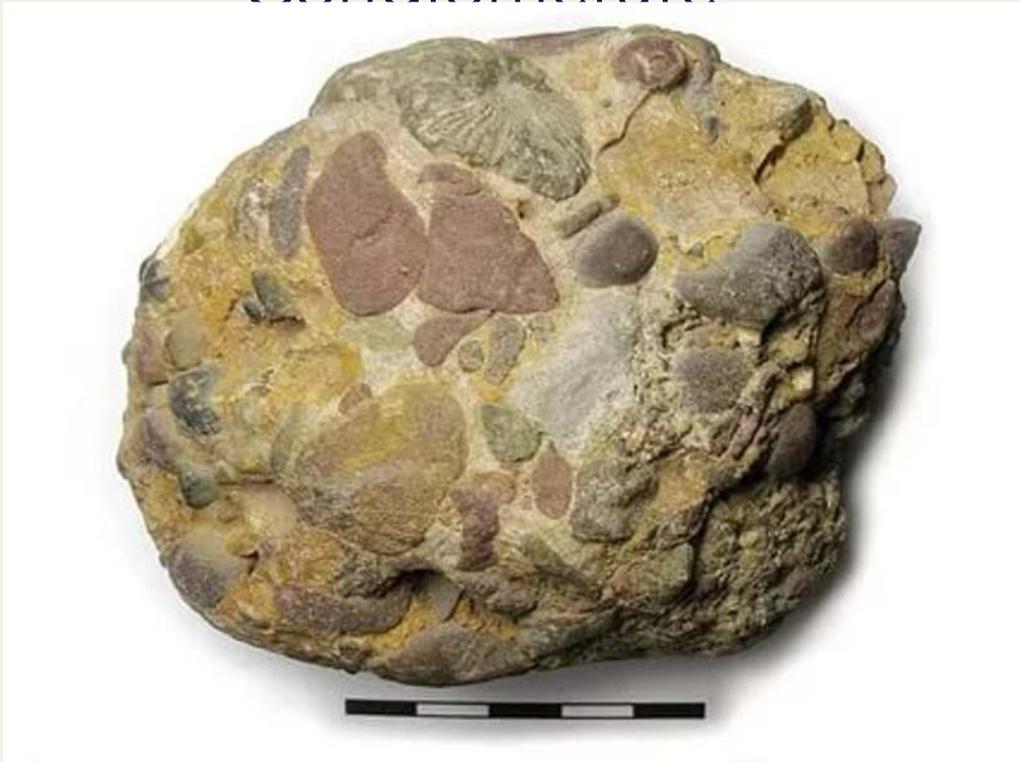
Igneous intrusions

Ogallala Formation

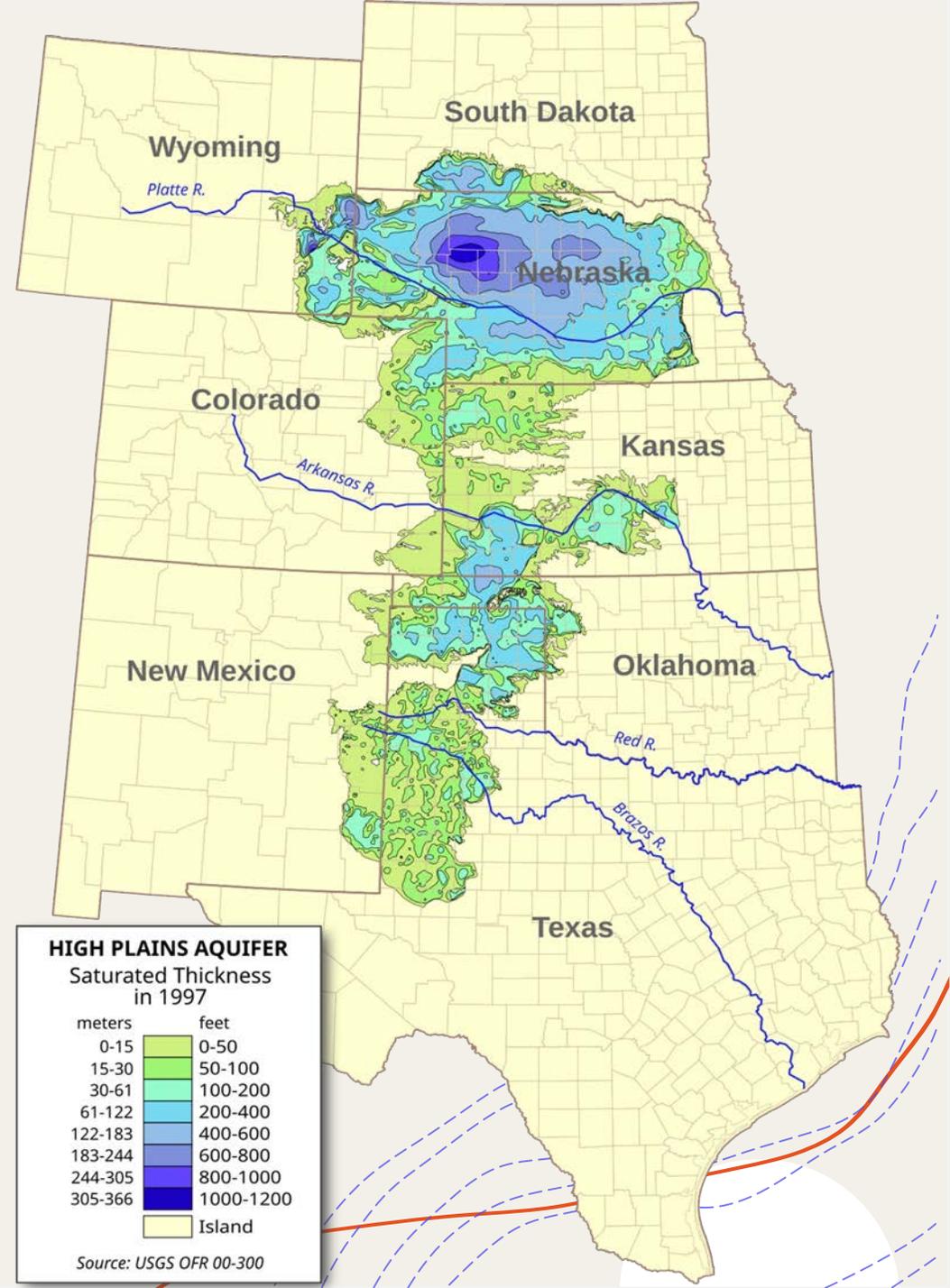
Had to form after Two
Buttes was exposed at the
surface

High Plains Aquifer

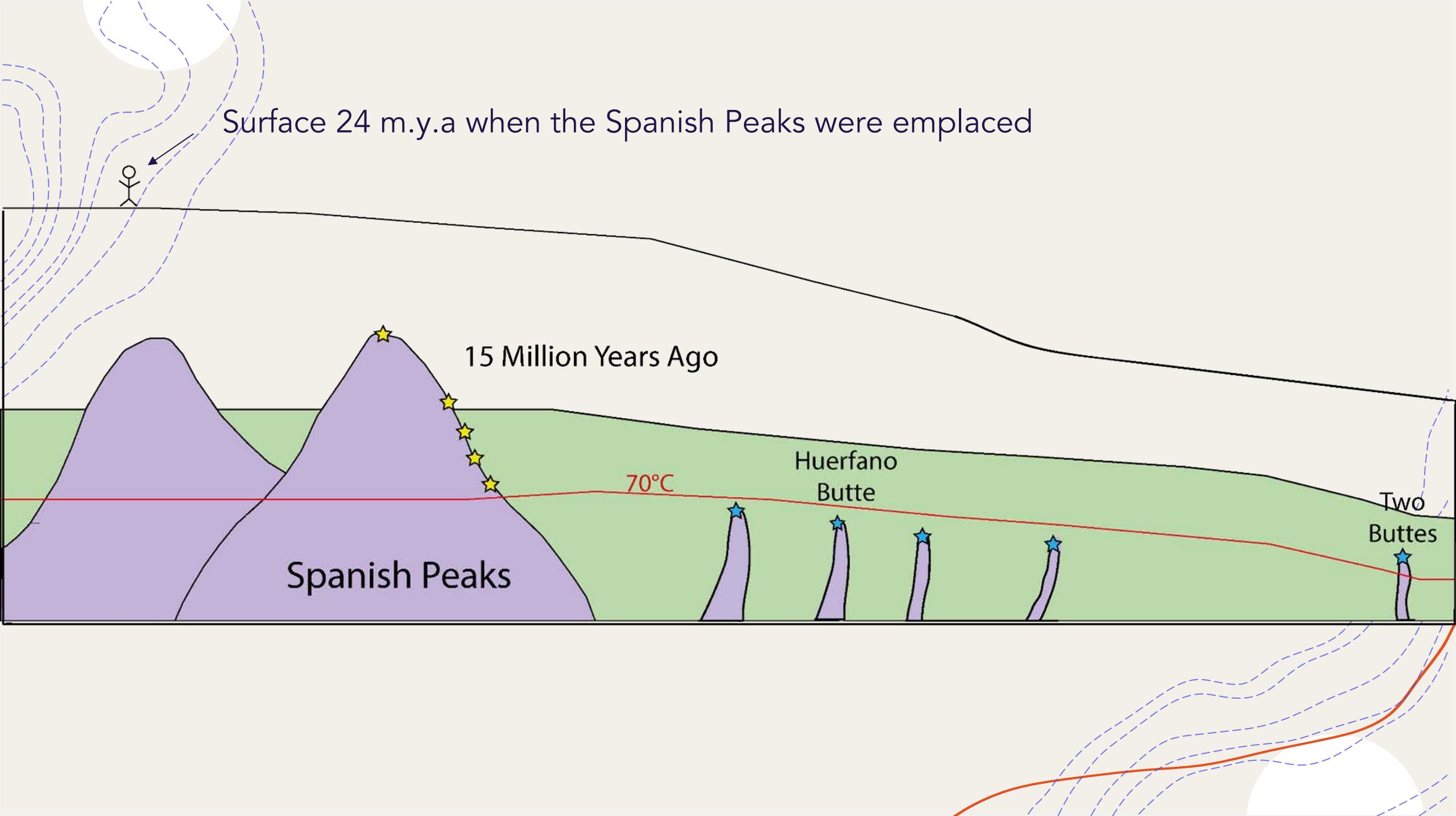
Conglomerate



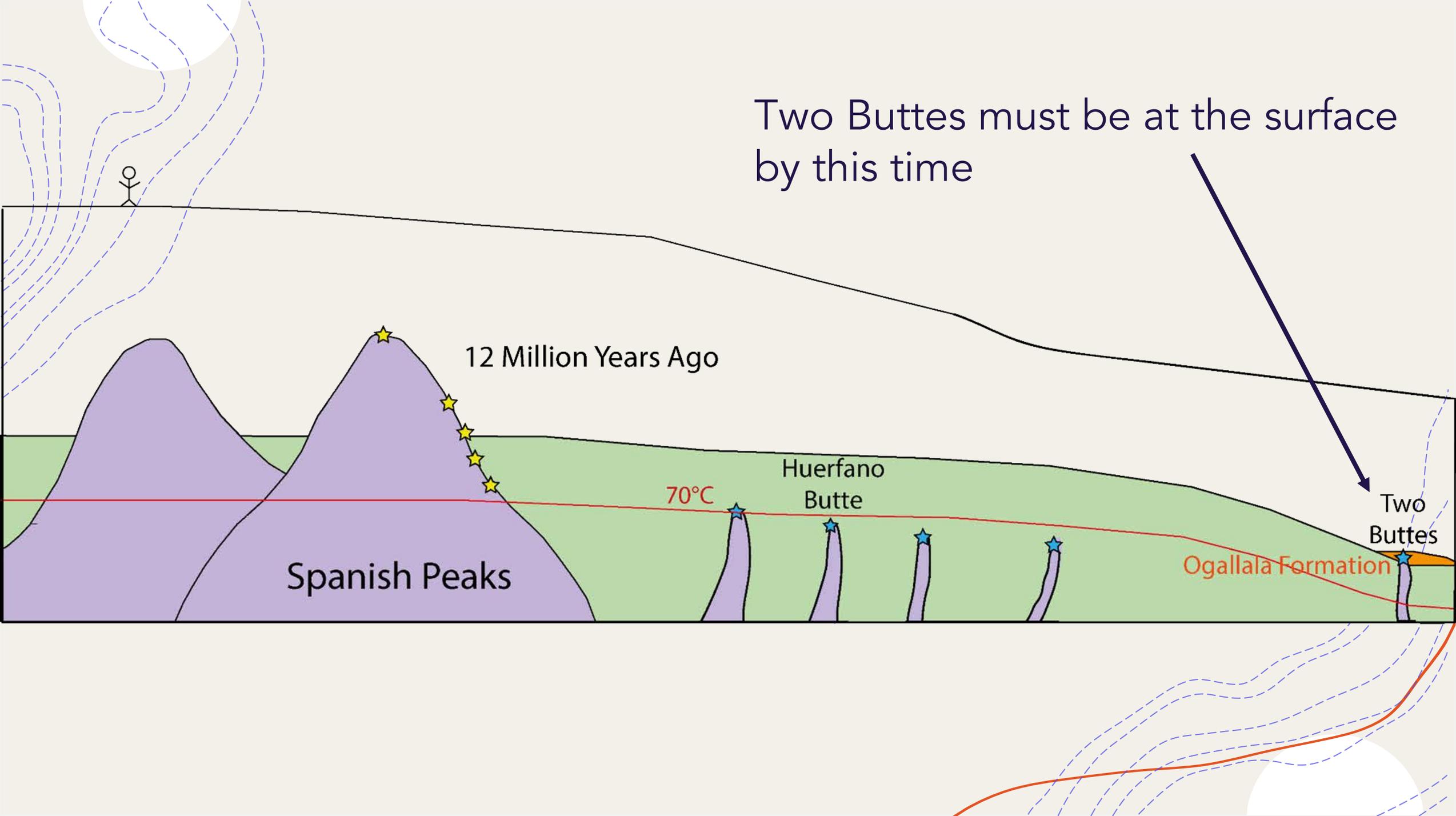
geologyscience.com

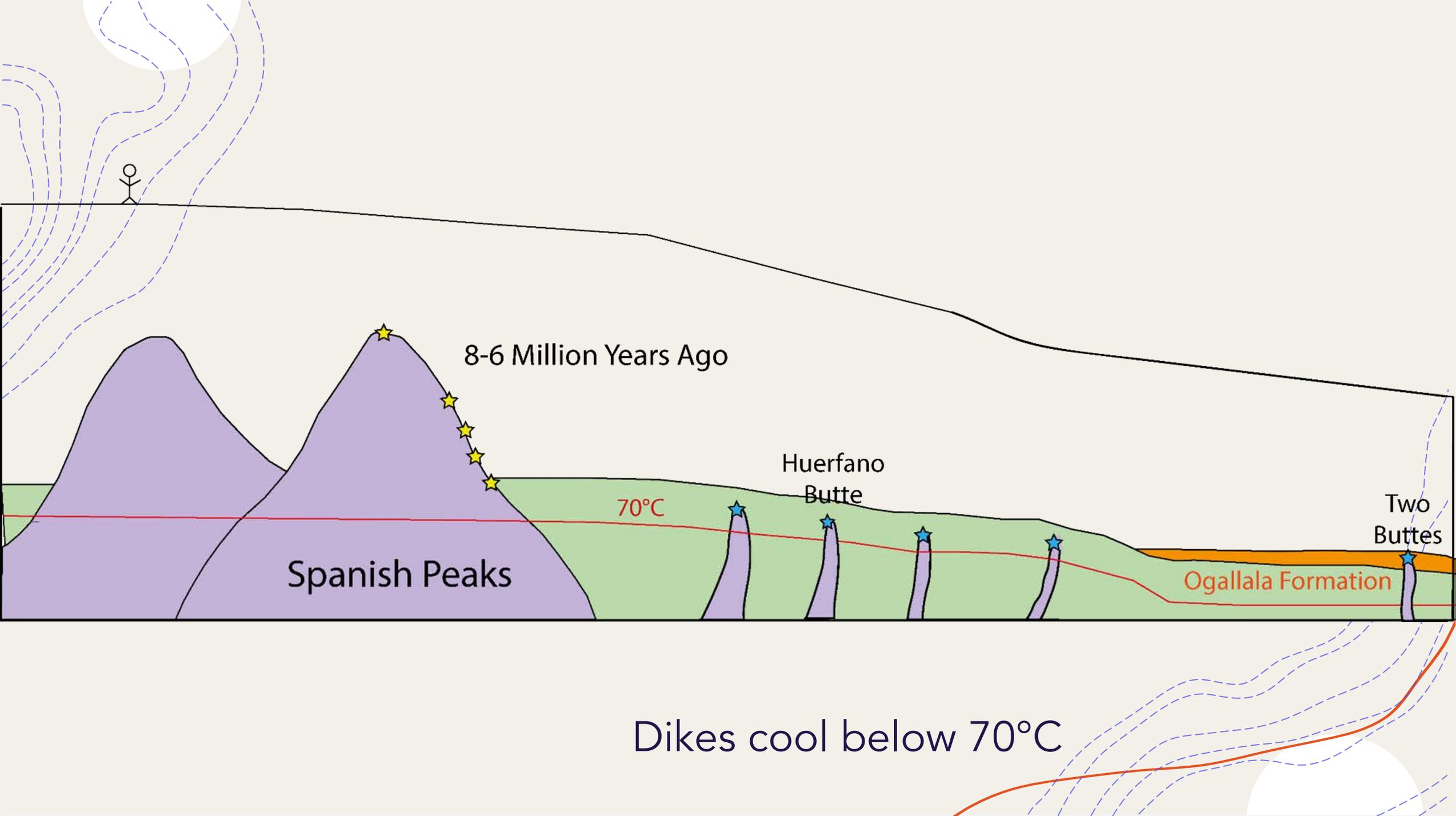


Surface 24 m.y.a when the Spanish Peaks were emplaced

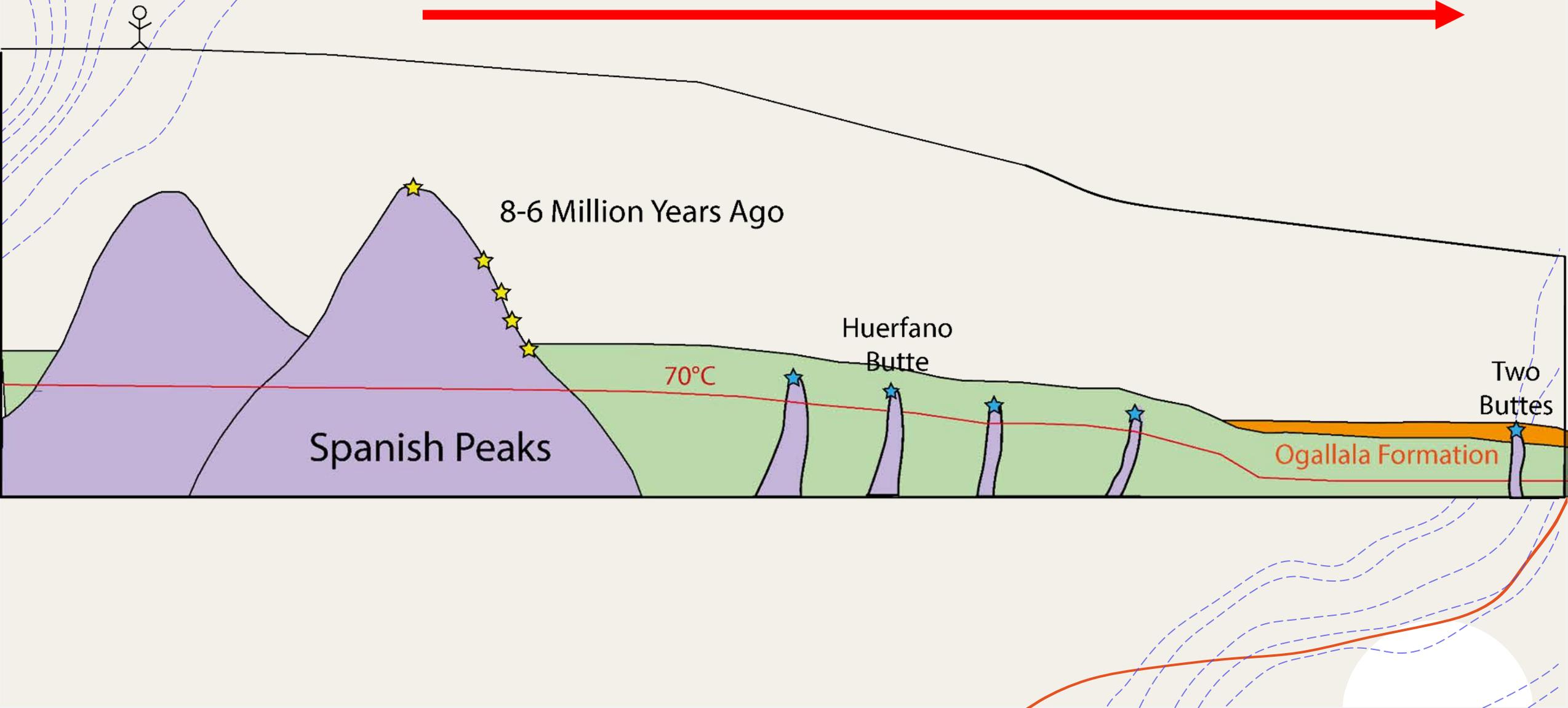


Two Buttes must be at the surface by this time

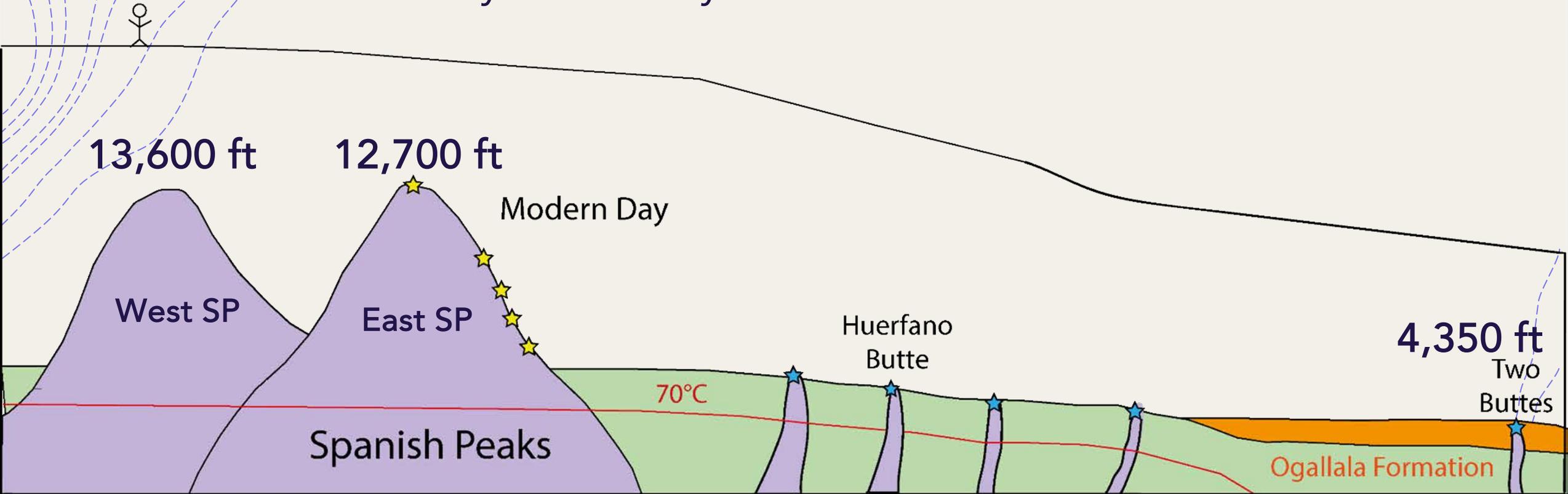


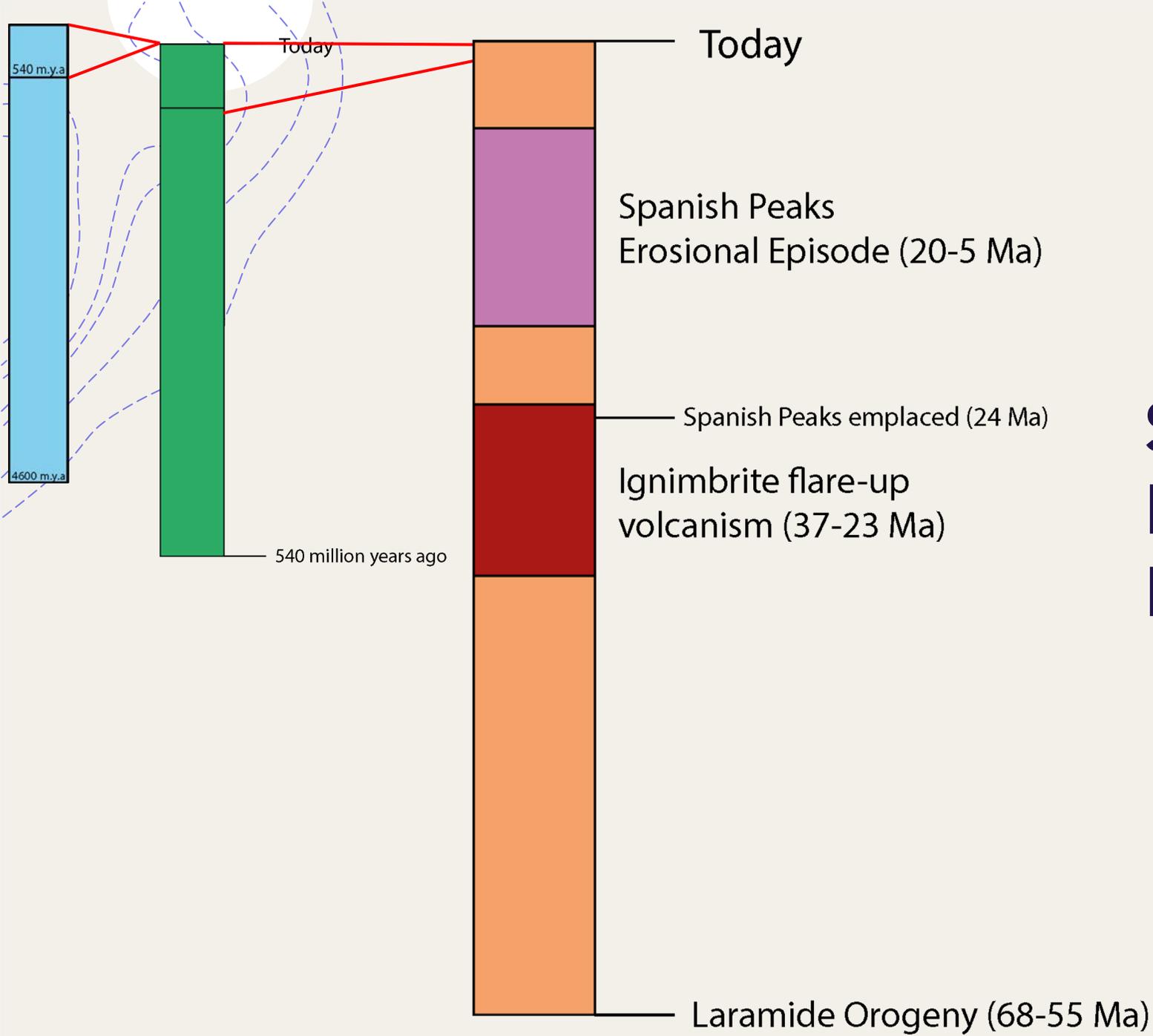


The Spanish Peaks erosional episode was experienced over a large area and continued till 6 m.y.a



Still have to erode 1.5 km from 6 m.y.a to today!



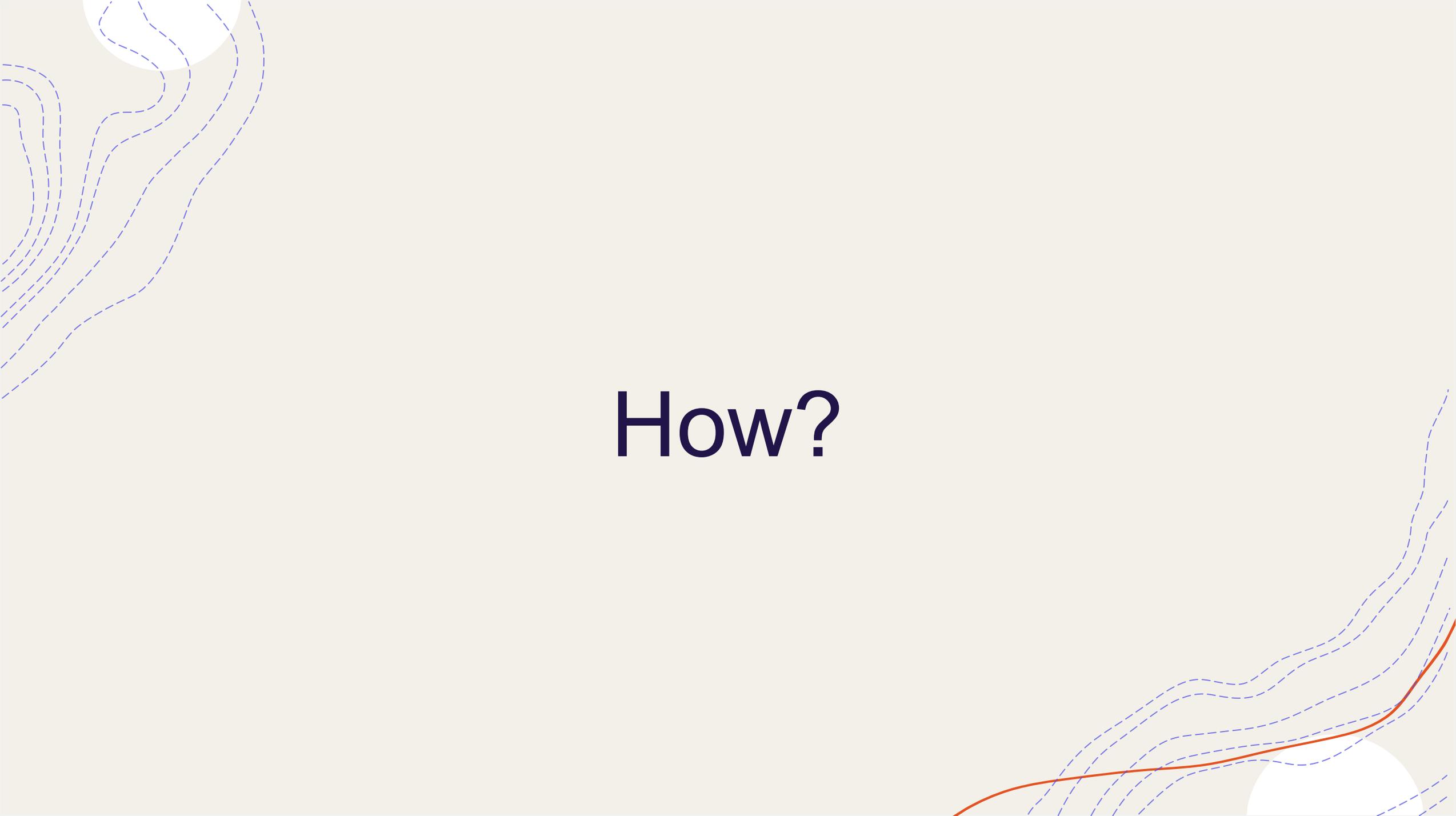


Southern Colorado's Recent Geologic History

1. The land surface at 24 m.y.a. was ~10,000 ft higher than it is today. All of this was removed since 19 m.y.a

1. Removal of material was *fast*. ~3,300ft/million year

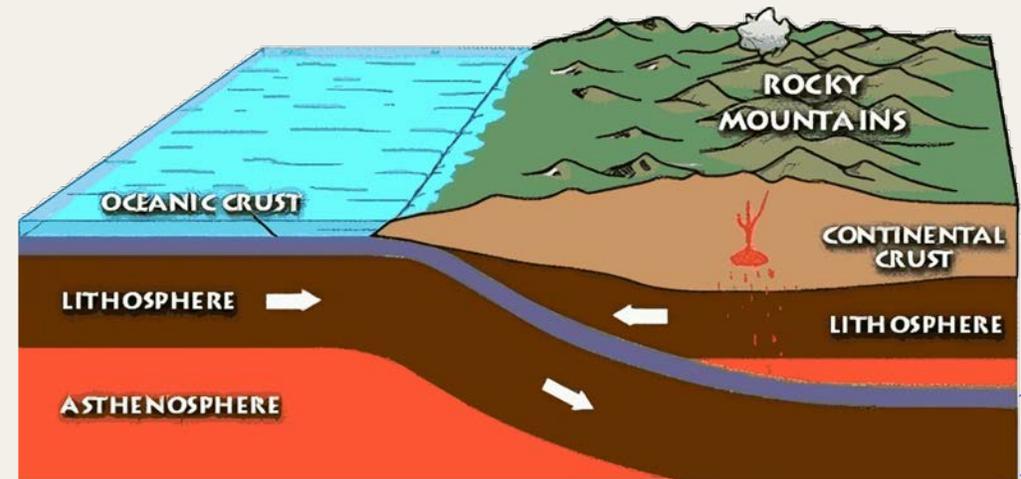
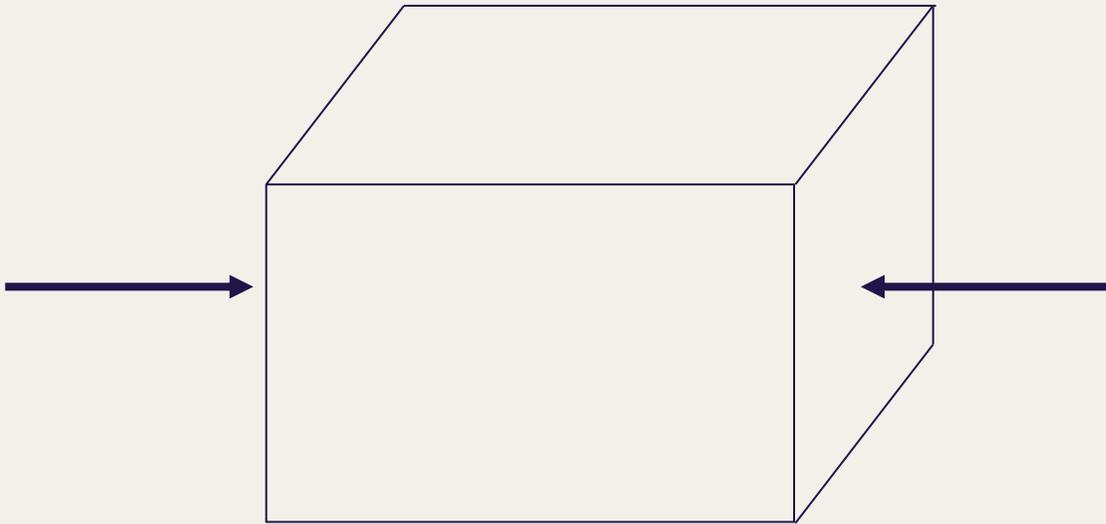
1. Erosion was experienced far out into the High Plains as far as the Kansas border (and maybe more!)

The background is a light beige color. In the top-left corner, there is a white circle partially cut off by the edge, with several blue dashed wavy lines extending downwards and to the right. In the bottom-right corner, there is another white circle partially cut off, with several blue dashed wavy lines extending upwards and to the left. A solid orange line also curves across the bottom-right area, following the general path of the dashed lines.

How?

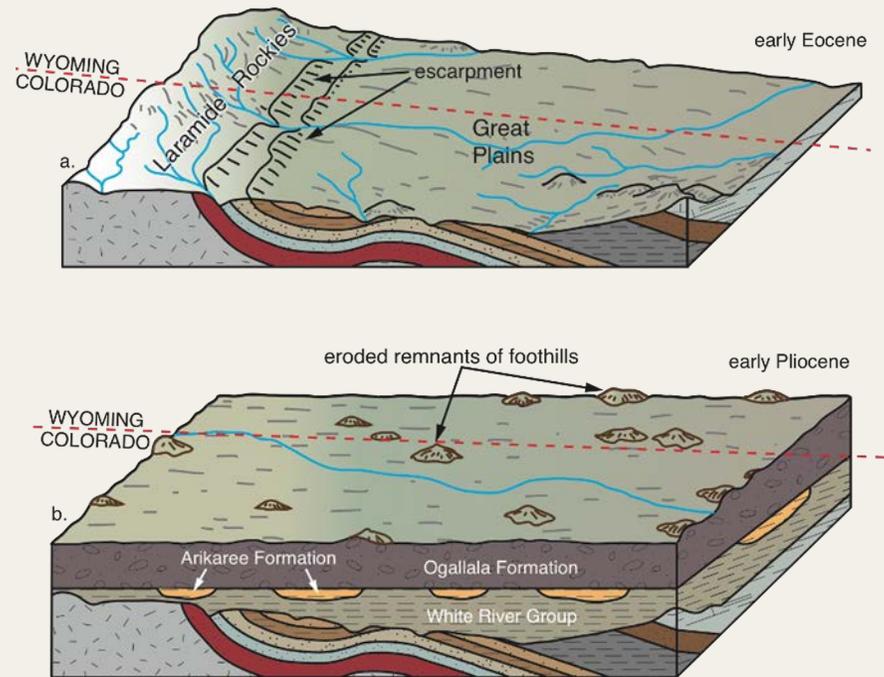
Mechanisms of rapid erosion

1. Orogeny = tectonic mountain building (horizontal displacement)



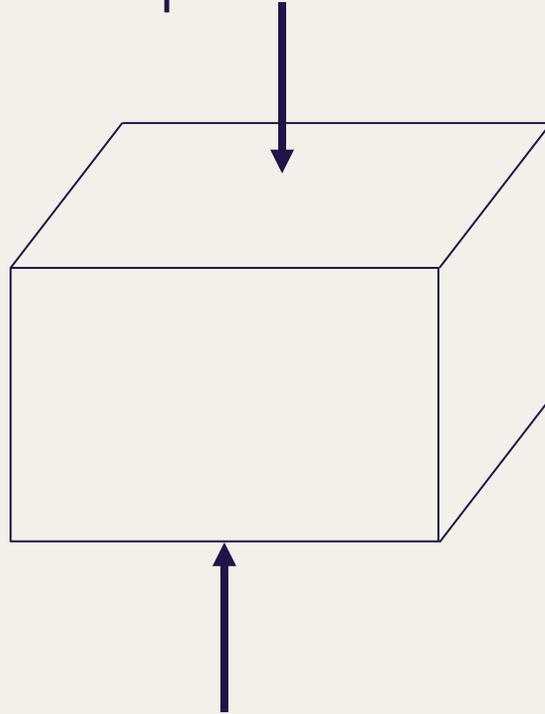
Mechanisms of rapid erosion

1. Orogeny = tectonic mountain building (horizontal displacement)

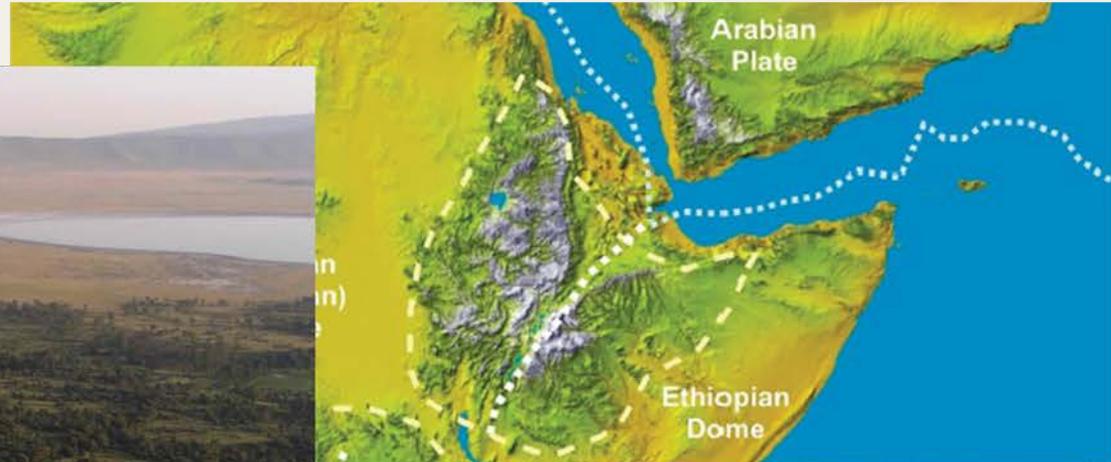


Mechanisms of rapid erosion

1. ~~Orogeny = tectonic mountain building (horizontal displacement)~~
2. Epeirogeny = vertical displacement of the crust



East African Rift supports high, flat plains



NOAA

Farallon Slab Subduction (Laramide Orogeny)

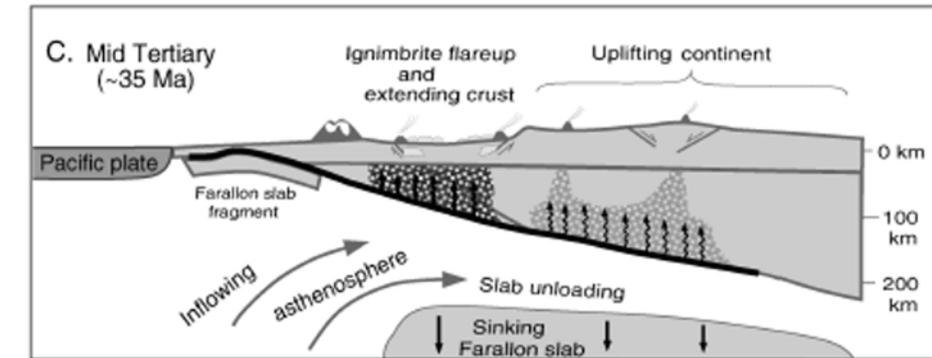
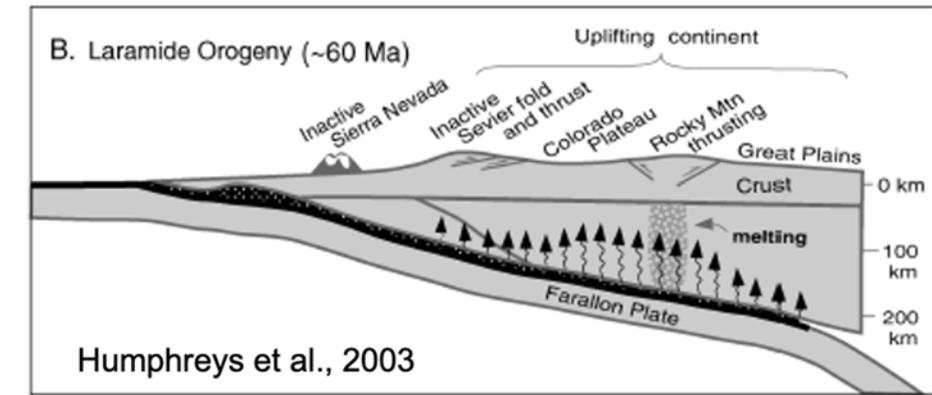
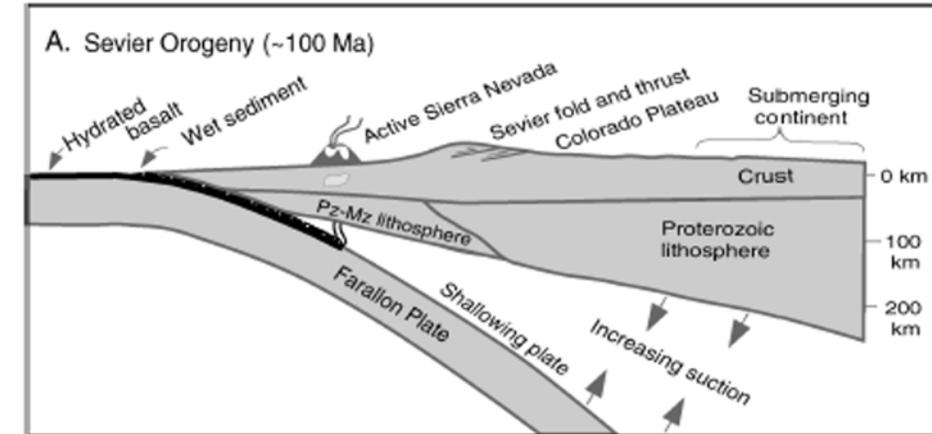
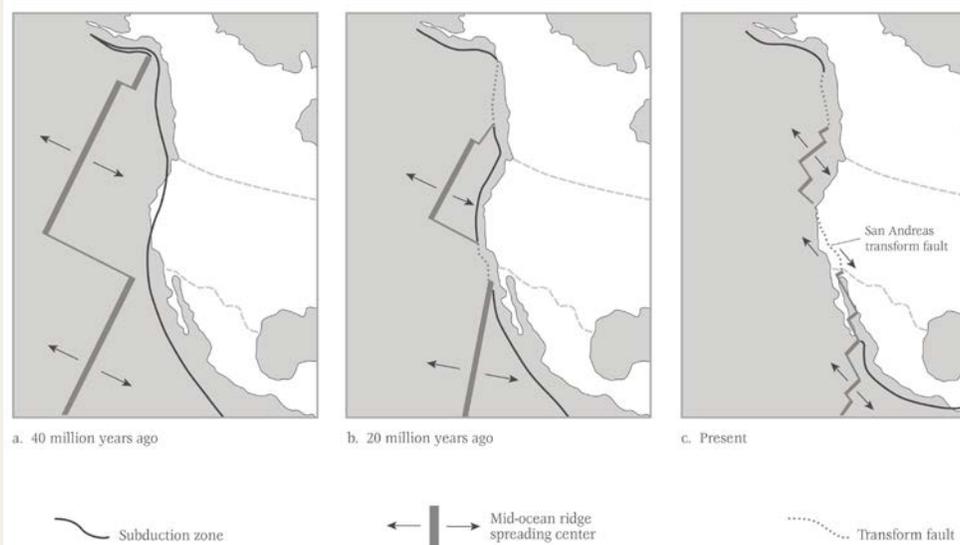
Today

Spanish Peaks
Erosional Episode (20-5 Ma)

Rio Grande Rift opens (28 Ma)

Ignimbrite flare-up
volcanism (37-23 Ma)

Laramide Orogeny (68-55 Ma)



Humphreys et al., 2003

Ignimbrite Flare-up Magmatism

Today

Spanish Peaks
Erosional Episode (20-5 Ma)

Rio Grande Rift opens (28 Ma)

Ignimbrite flare-up
volcanism (37-23 Ma)

Laramide Orogeny (68-55 Ma)



Rio Grande Rifting

Today

Spanish Peaks
Erosional Episode (20-5 Ma)

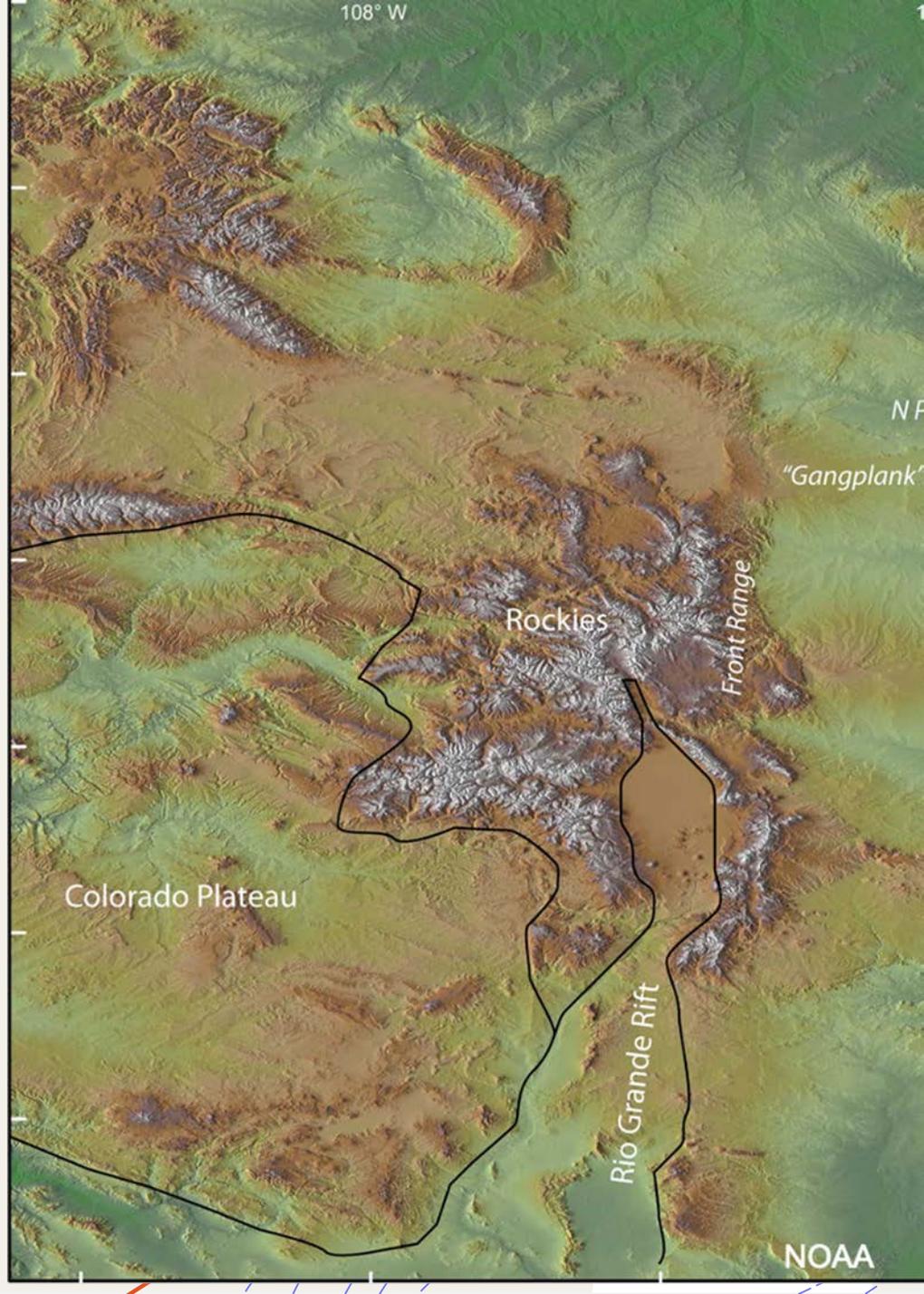
Rio Grande Rift opens (28 Ma)

Ignimbrite flare-up
volcanism (37-23 Ma)

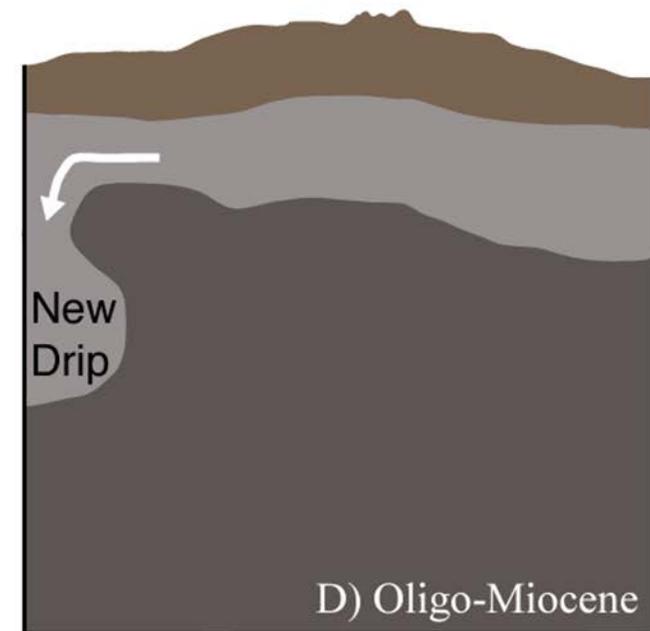
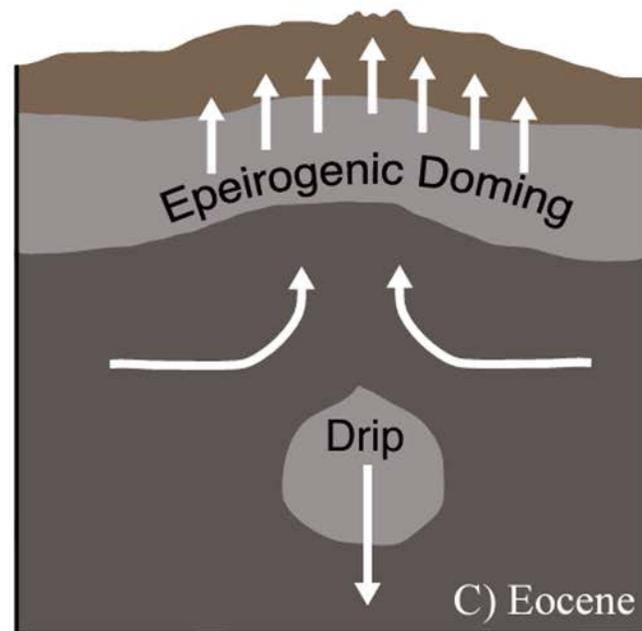
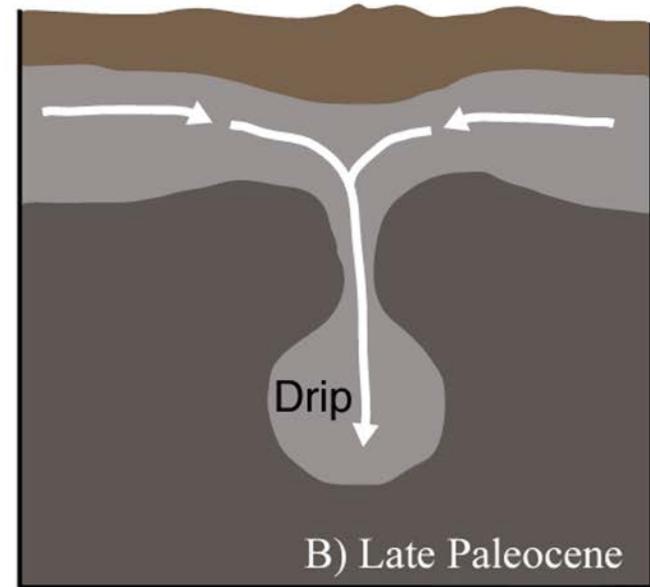
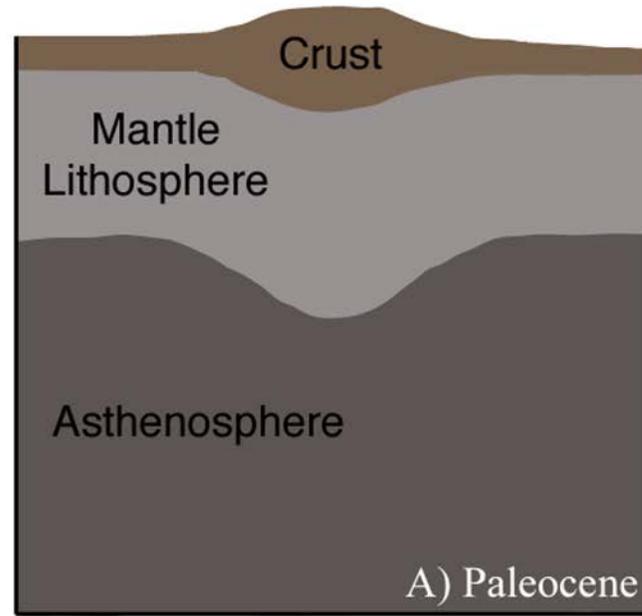
Laramide Orogeny (68-55 Ma)



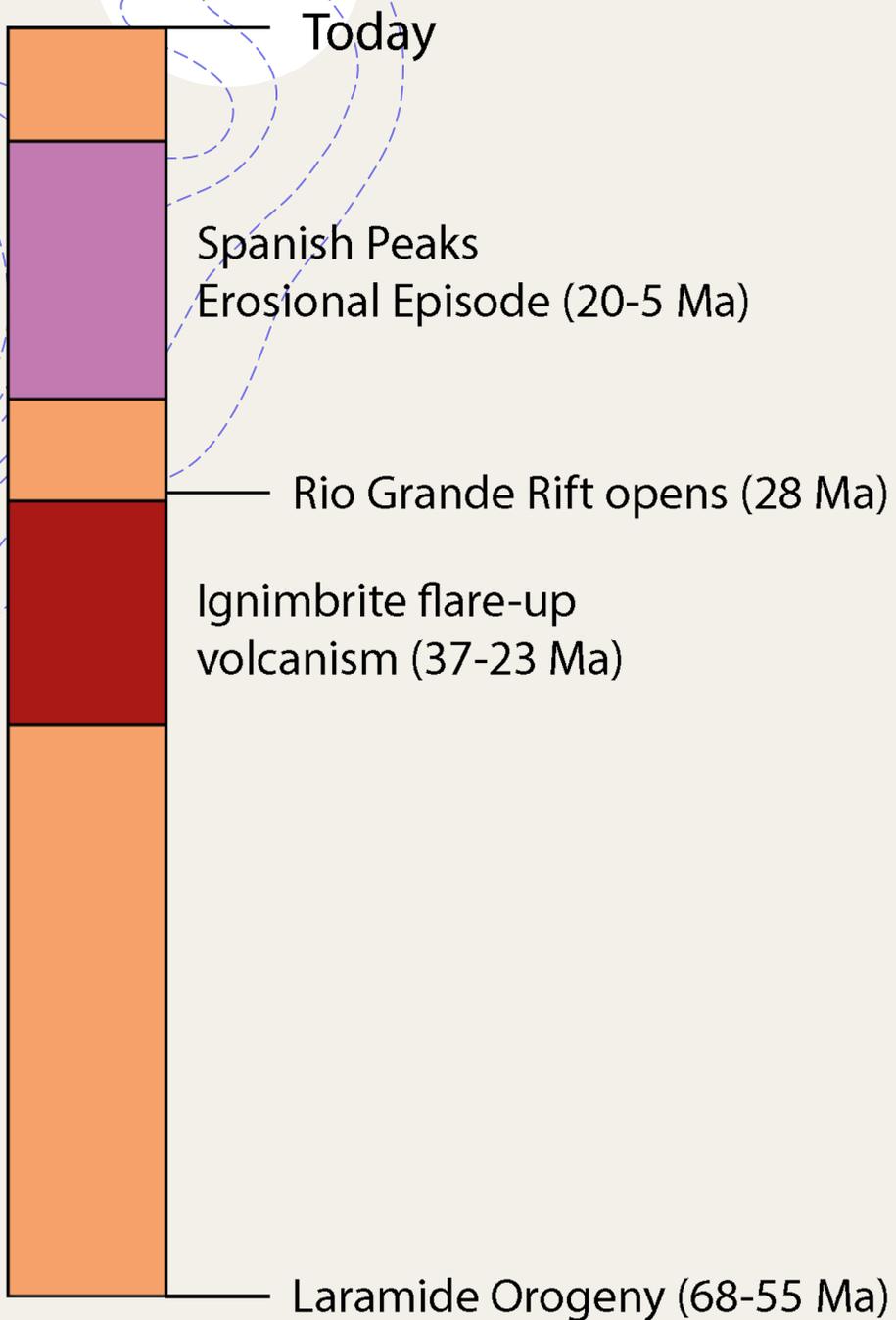
Abbott and Cook



A theoretical mantle drip



Abbott et al., 2022



Many explanations,
not one final.

But, knowing the
timing of this event is
crucial to narrow
them down.

A special place for all...



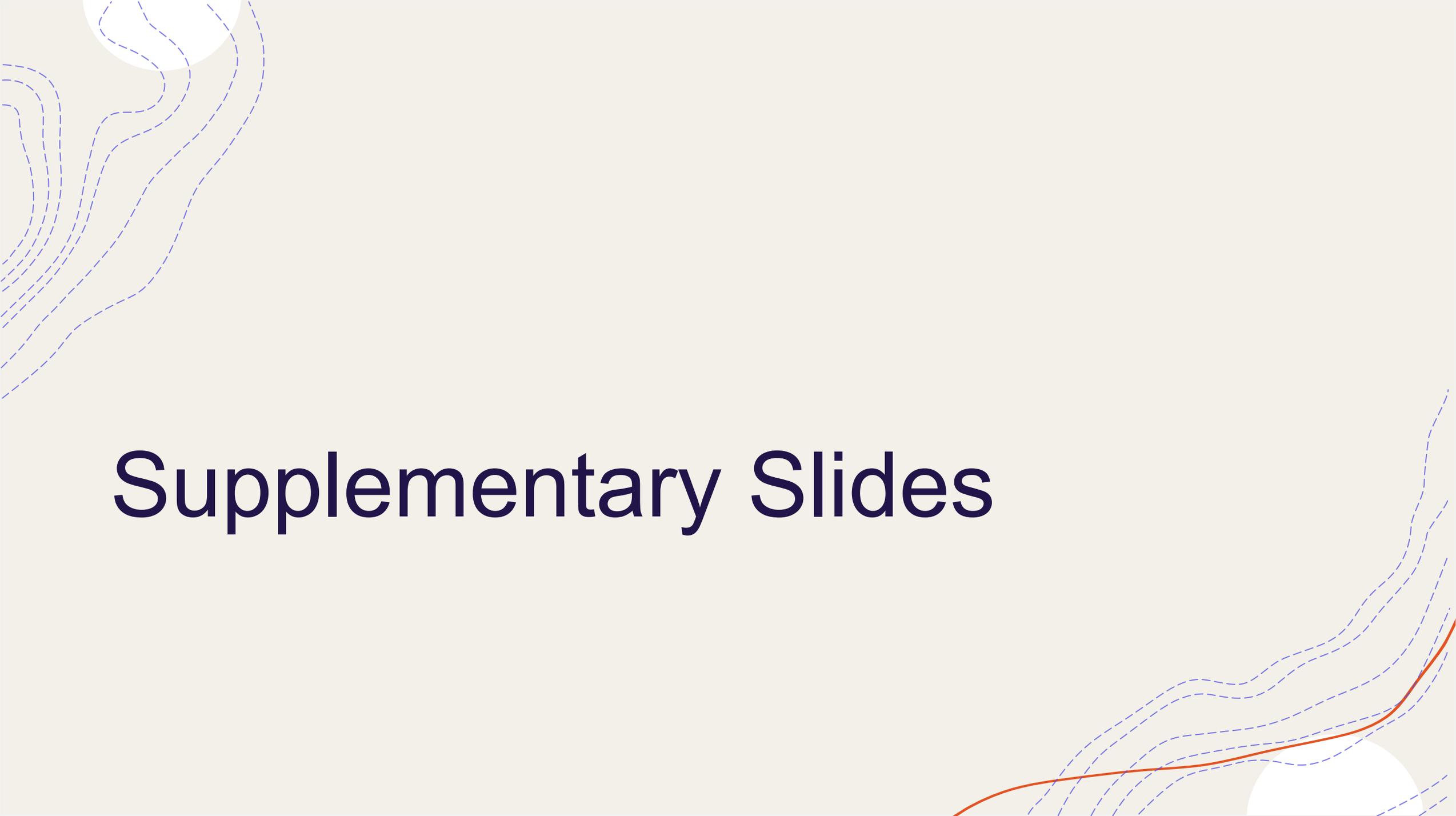
Photo by Aaron Spong

Thank you for listening

Acknowledgements:

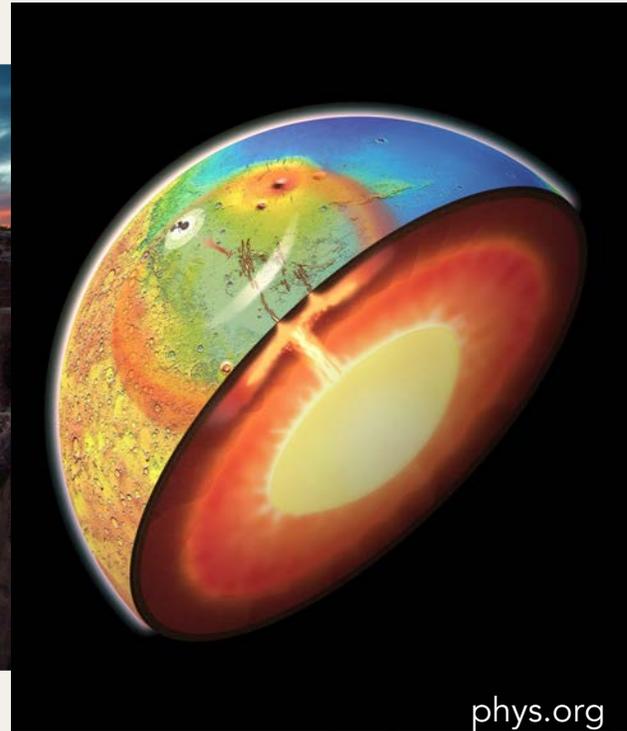
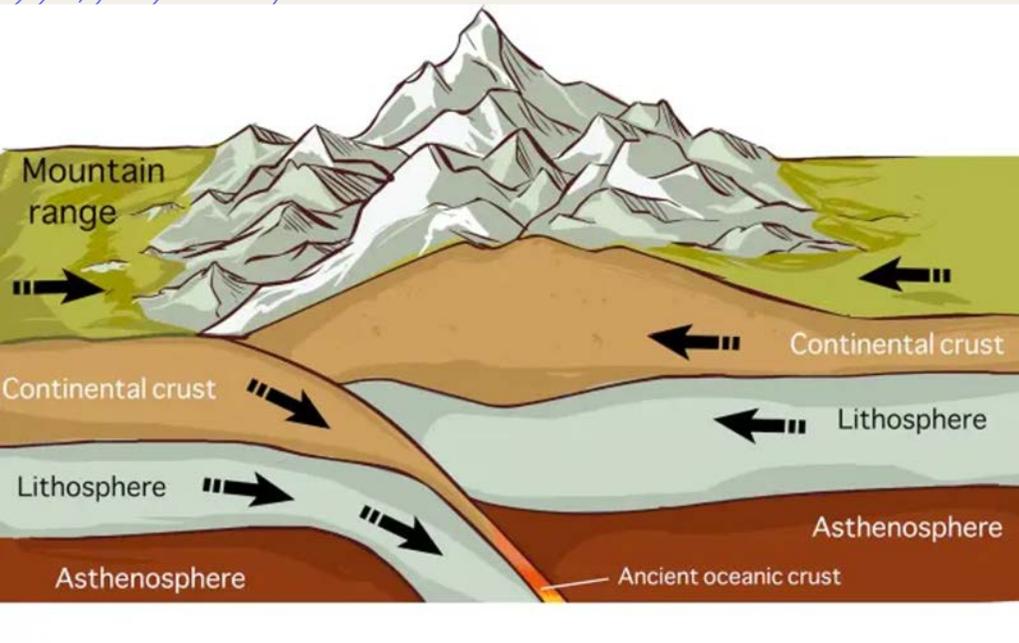
- + Marilyn and the Francisco Fort Day team
- + Aidan Olsson (CU Undergrad)
- + Skye Fernandez (recent CU graduate)
- + Dr. Becky Flowers
- + Dr. Jim Metcalf
- + Dr. Rachel Landman
- + CU UROP Funding
- + CU TUnDRA Funding
- + CU Libraries



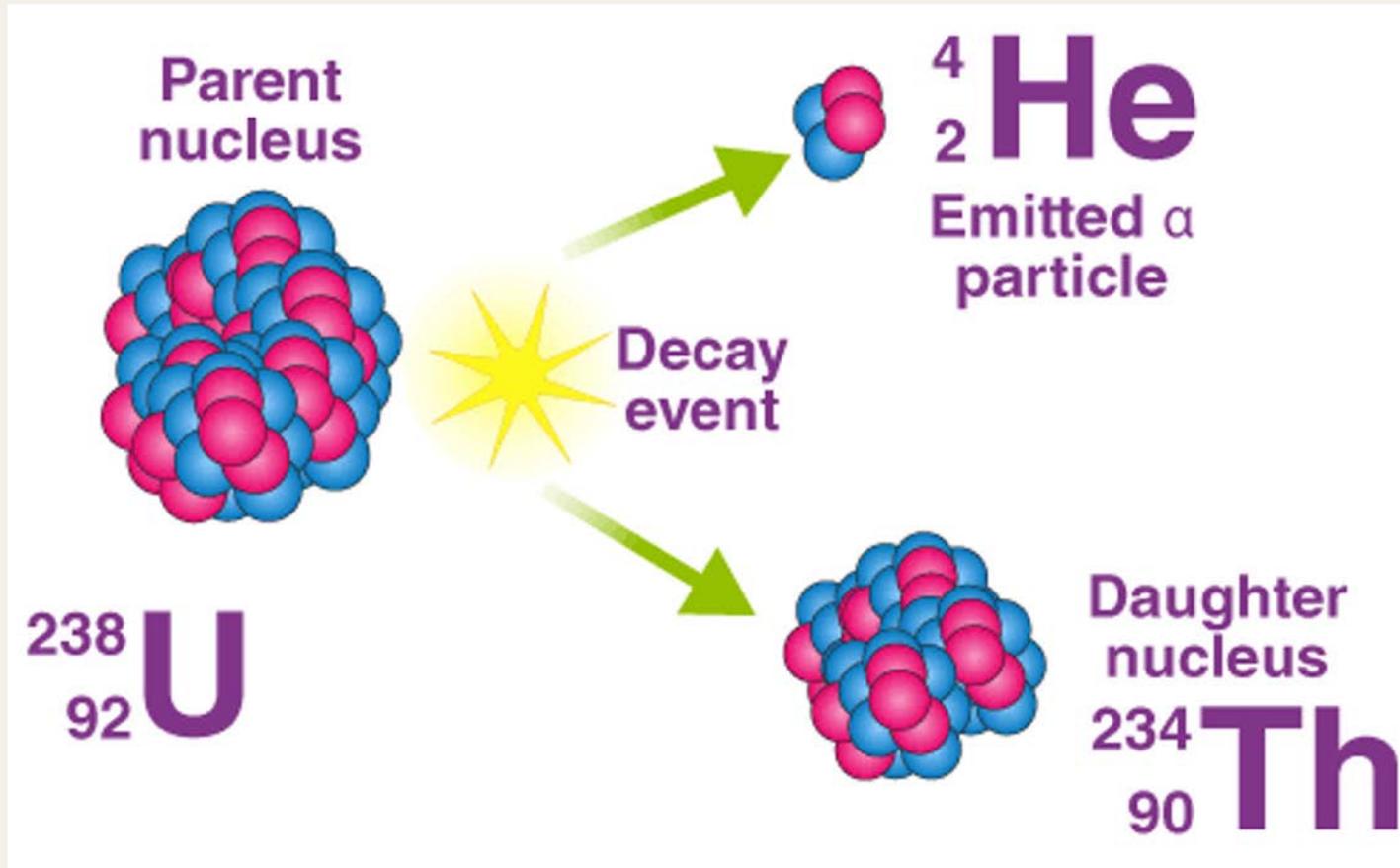
The background features a light beige gradient. In the top-left corner, there is a white circle partially cut off by the edge, with several blue dashed wavy lines extending downwards and to the right. In the bottom-right corner, there is another white circle partially cut off, with several blue dashed wavy lines extending upwards and to the left. A solid orange line also curves across the bottom-right area, overlapping the blue dashed lines.

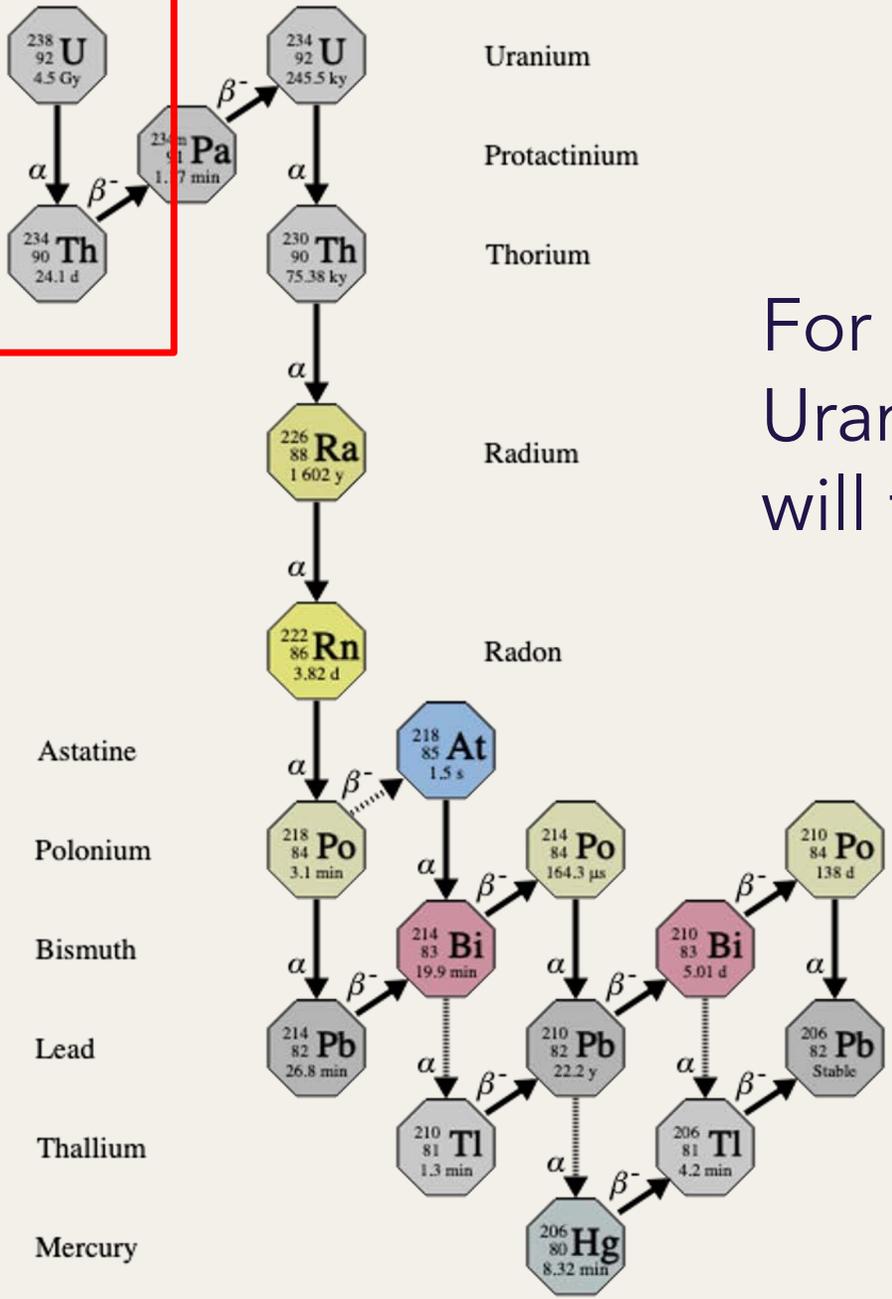
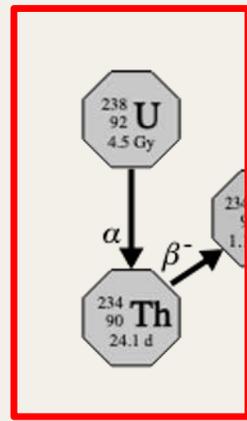
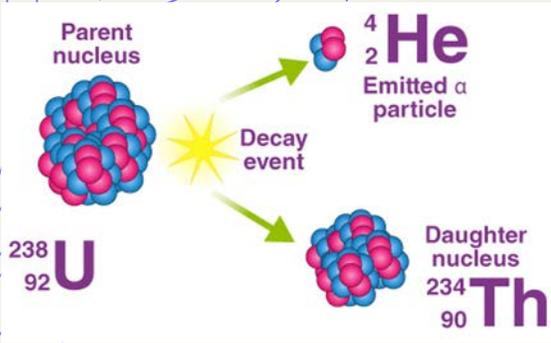
Supplementary Slides

What can cause temperature to change?



Decay of Uranium





Uranium
Protactinium
Thorium
Radium
Radon
Astatine
Polonium
Bismuth
Lead
Thallium
Mercury

For half of Earth's total Uranium to decay, this will take 4.5 billion years



From rock to data



From rock to data

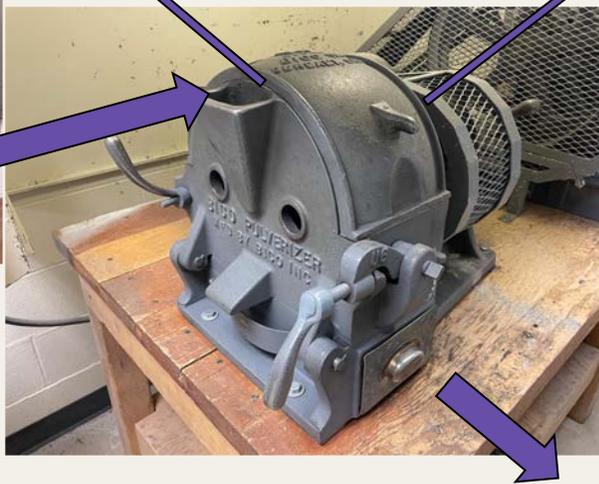
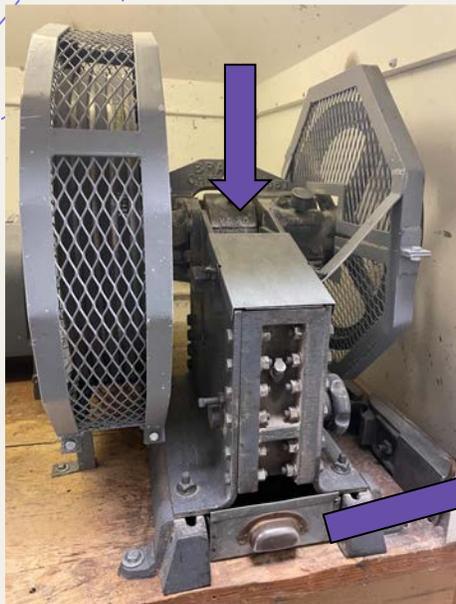
Sampling in the High Plains



Aidan at the Eagle Rock Dike, NM

1. Igneous = contains trace minerals required
1. Intrusive = solidified below the 'closure' temp
1. Young = shorter history to interpret

From rock to data



From rock to data



Measures Helium

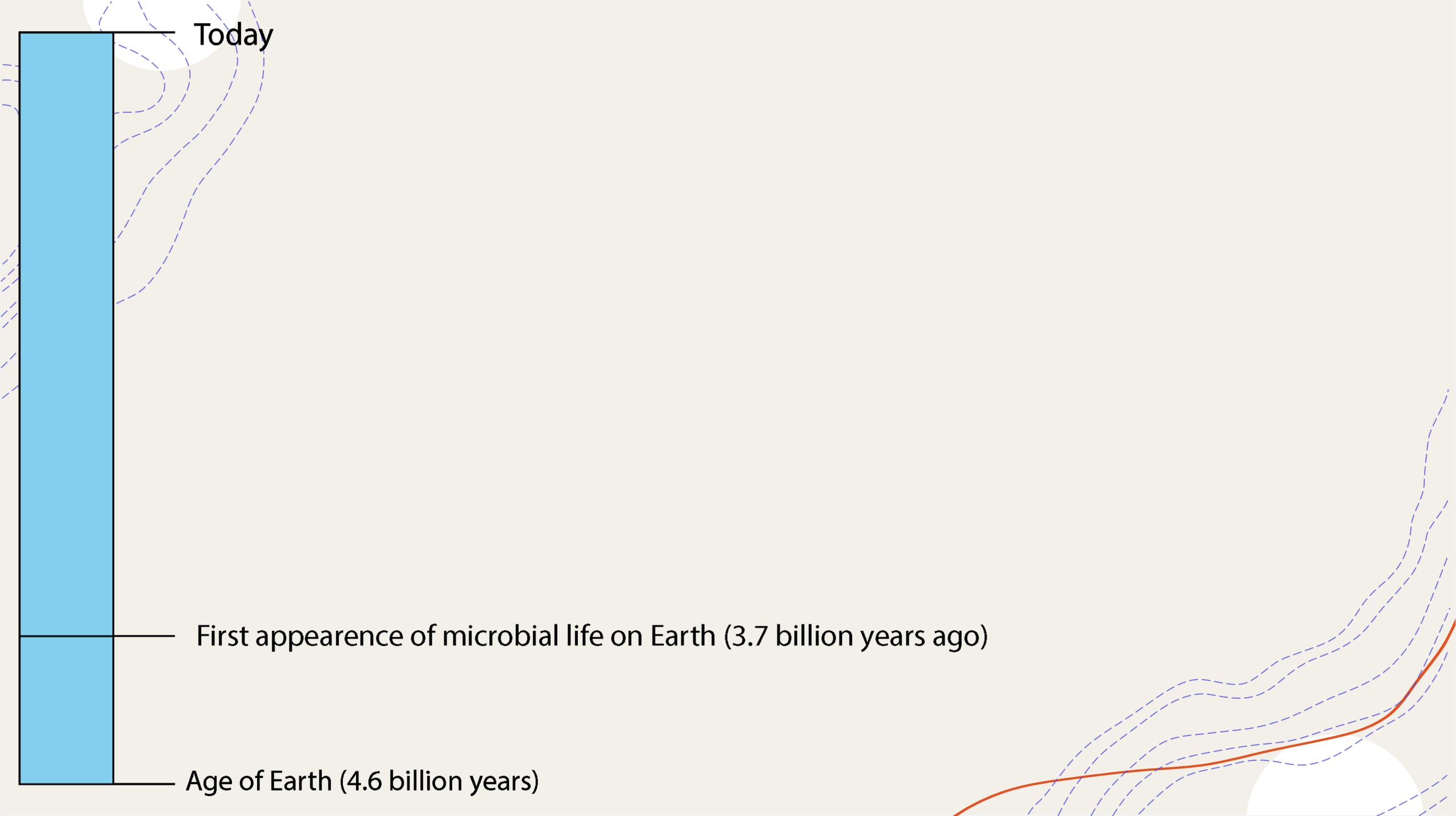


Measures Uranium and Thorium

Today

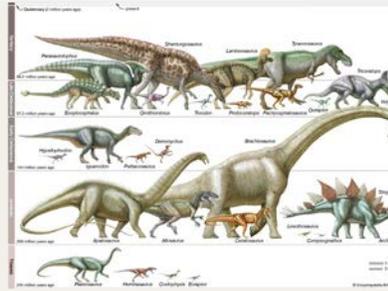
First appearance of microbial life on Earth (3.7 billion years ago)

Age of Earth (4.6 billion years)



Today

Complex animal life evolves (540 million years ago)



Microbial Planet

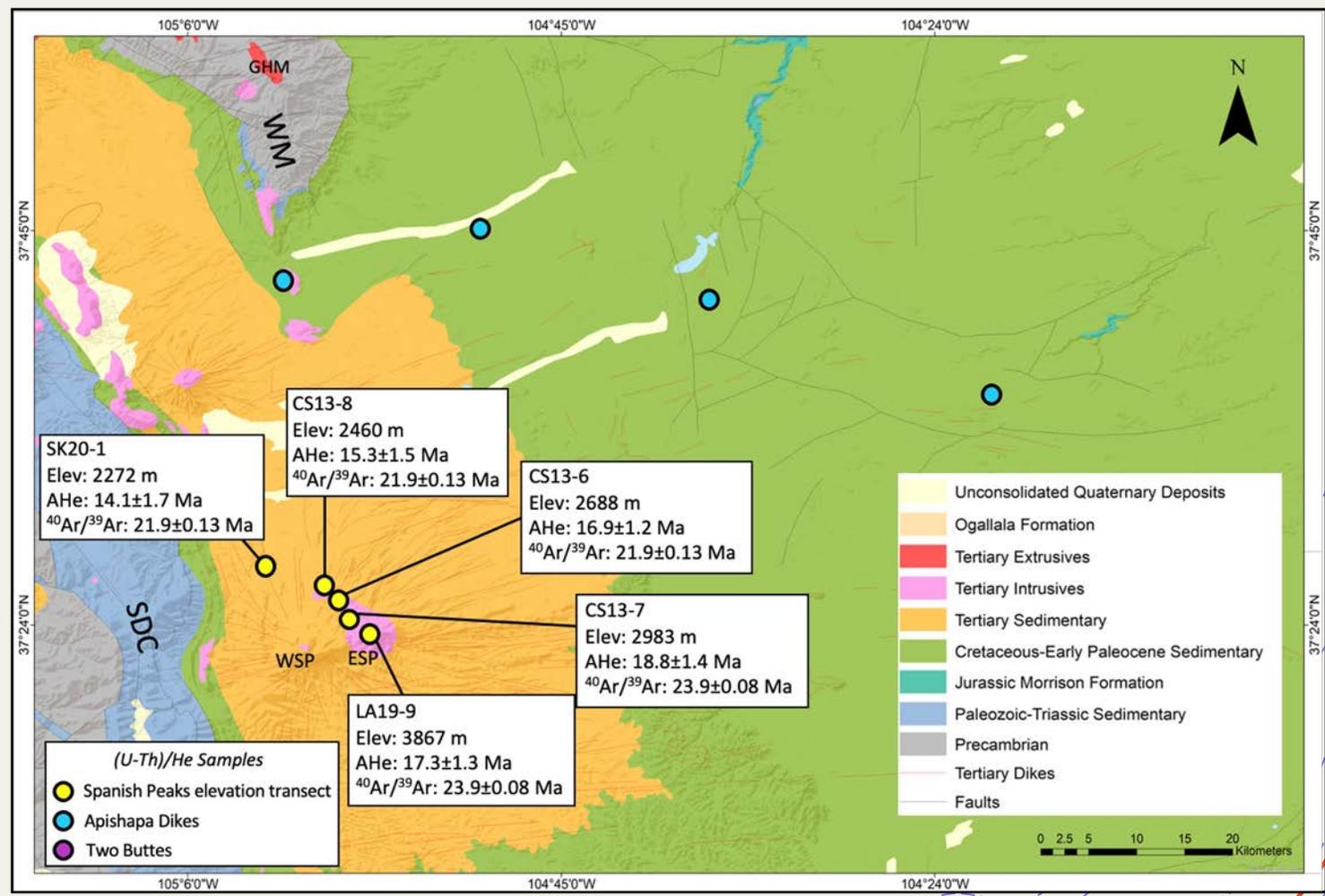
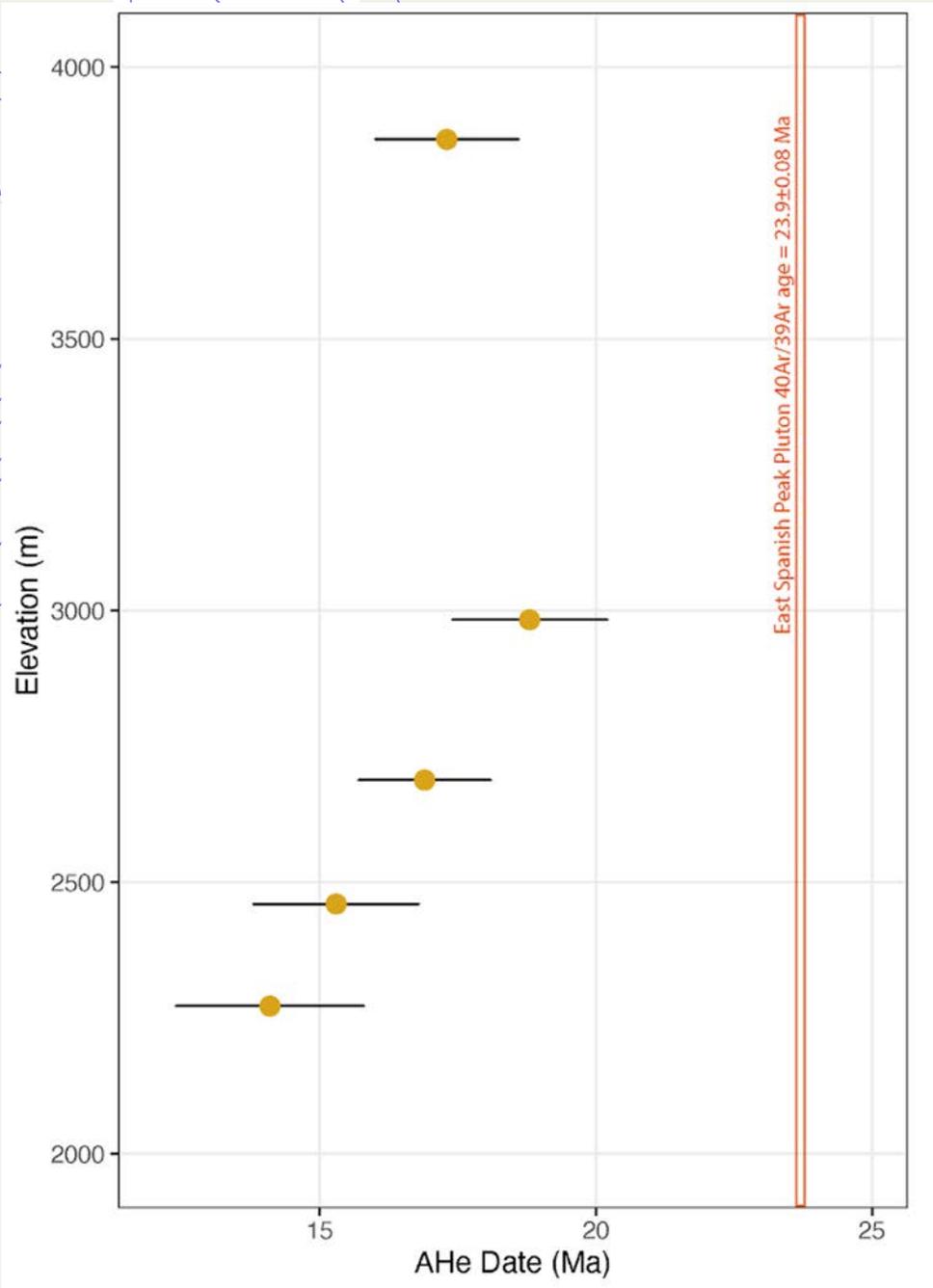


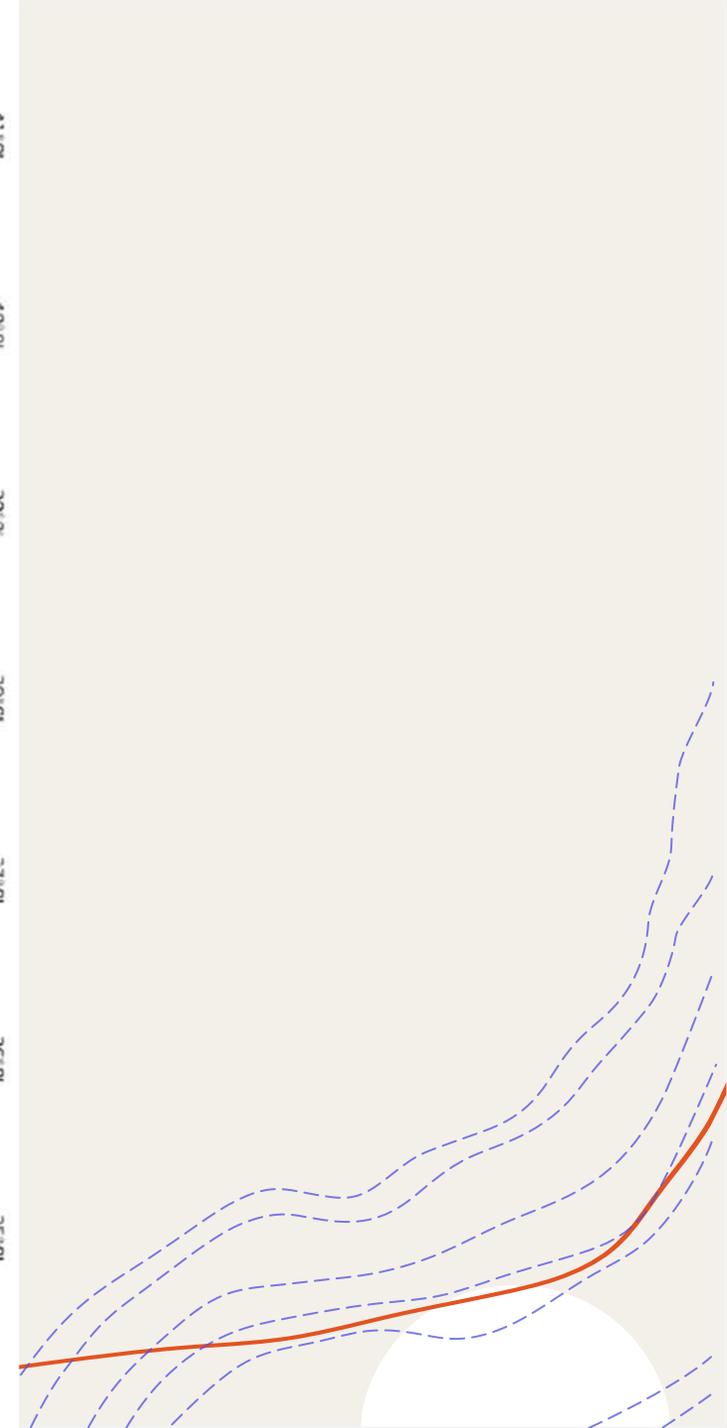
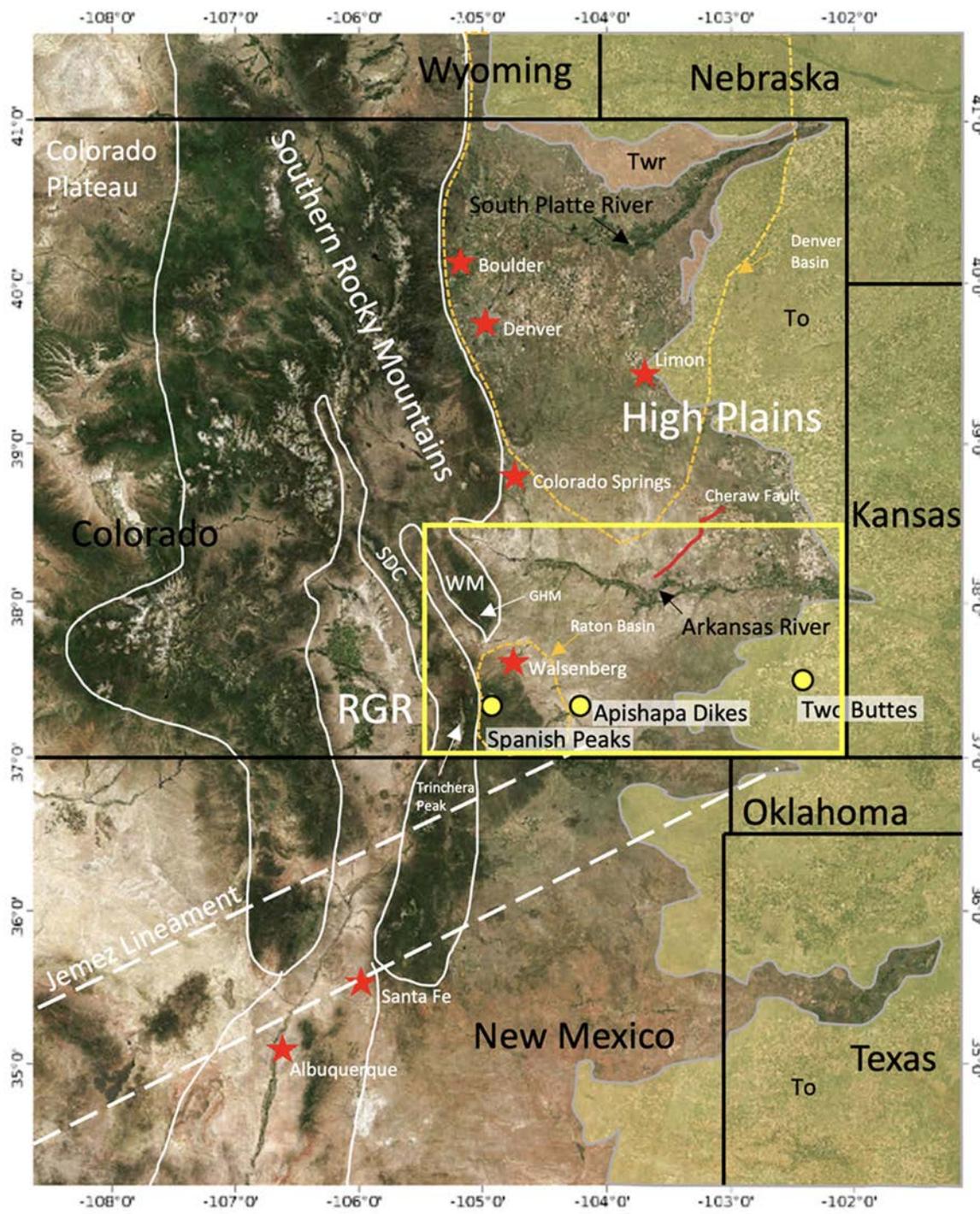
Yale University Press

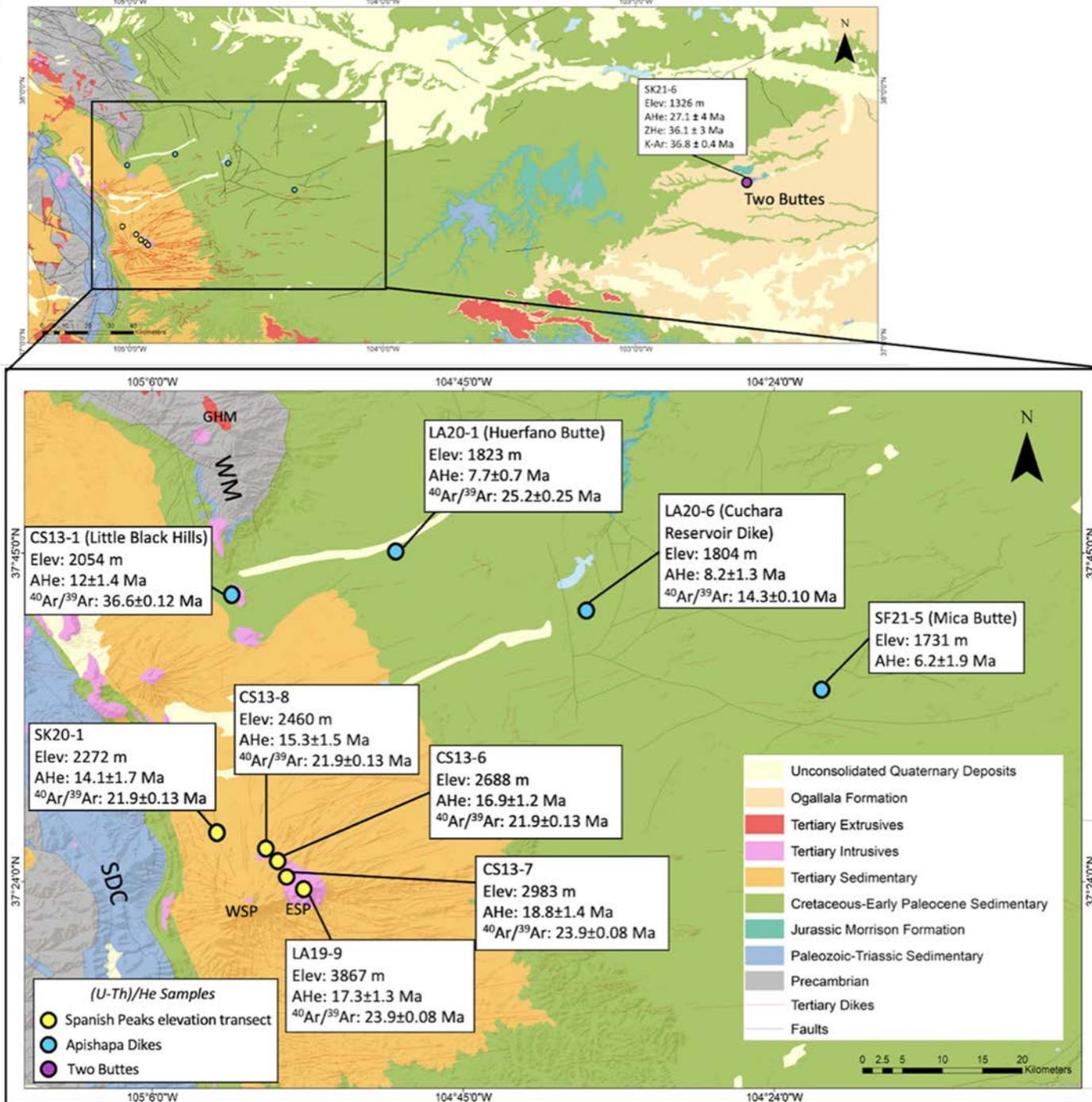


First appearance of microbial life on Earth (3.7 billion years ago)

Age of Earth (4.6 billion years)







ERA	PERIOD	DEPOSITIONAL UNITS	FORMATION	
Cenozoic	Tertiary	Miocene	Ogallala	Ogallala Fm
		Eocene	White River Equivalents (WRE)	WRE volcanics and volcanoclastics
			Raton Basin Fill	Farisita Fm
	Huerfano Fm			
	Cuchara Fm			
	Poison Canyon Fm			
	Cretaceous	Western Interior Seaway (WIS)	Raton Fm	
			Vermejo Fm	
			Trinidad SS	
			Pierre Shale	
Niobrara Fm				
Benton Group				
Dakota Group + Purgatoire Fm				
Jurassic	Pre-WIS	Morrison Fm		
		Entrada Fm		
		Dockum Group		
Paleozoic	Permian	Ancestral Rockies sediments	Sangre de Cristo Fm	

Spanish Peaks	
Thickness (m)	Total depth from top of unit (m)
0m to very thin	
300m+	
0-366m	0-366m
0-610m	0-976m
0-1524m	0-2500m
0-762m	0-3262m
0-610m	0-610m
0-116m	0-726m
0-79m	0-805m
396-701m	396-1506m
152-274m	548-1780m
107-229m	655-2009m
30-60m	685-2069m
46-122m	46-122m
12-30m	58-152m
0-37m	58-189m
unknown	

- ★ LA19-9
- ★ CS13-7
- ★ CS13-6
- ★ CS13-8
- ★ SK20-1

Apishapa Dikes	
Thickness (m)	Total depth from top of unit (m)
0m to very thin	
300m+	
0m to very thin	
0-610m	0-610m
0-116m	0-726m
0-79m	0-805m
396-701m	396-1506m
152-274m	548-1780m
107-229m	655-2009m
30-60m	685-2069m
46-122m	46-122m
12-30m	58-152m
0-37m	58-189m
unknown	

- ★ CS13-1
- ★ LA20-1
- ★ LA20-6
- ★ SF21-5

Two Buttes	
Thickness (m)	Total depth from top of unit (m)
Variable (< several hundred m)	
300m+	
0m to very thin	
~914m	
46-122m	46-122m
12-30m	58-152m
0-37m	58-189m
unknown	

- ★ SK21-6

