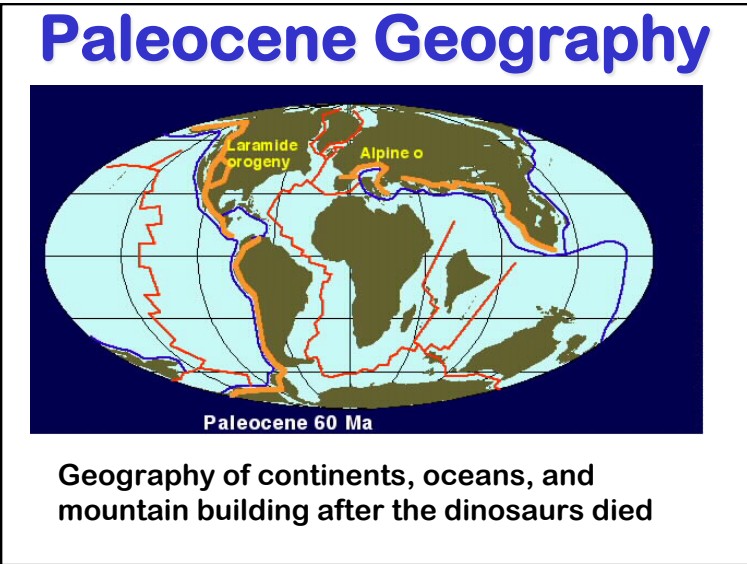


# EXPLAIN

## 3. Past 50 Million Years



### PETM – 56 M yr ago

- Global warming about 6 °C (11 °F) in about 20,000 years, lasted about 170,000 years
- Invasion of enormous amount of plant-derived CO<sub>2</sub> into oceans
- Acidification – dissolving of CaCO<sub>3</sub> in ocean sediments – mass extinction

CO<sub>2</sub> release recovers in ~100,000 yrs

CO<sub>2</sub> in recovers in ~100,000 yrs

Deep ocean warms

Ocean temp. recovers in ~100,000 yrs

Temp

Age, million years

Land

Sea

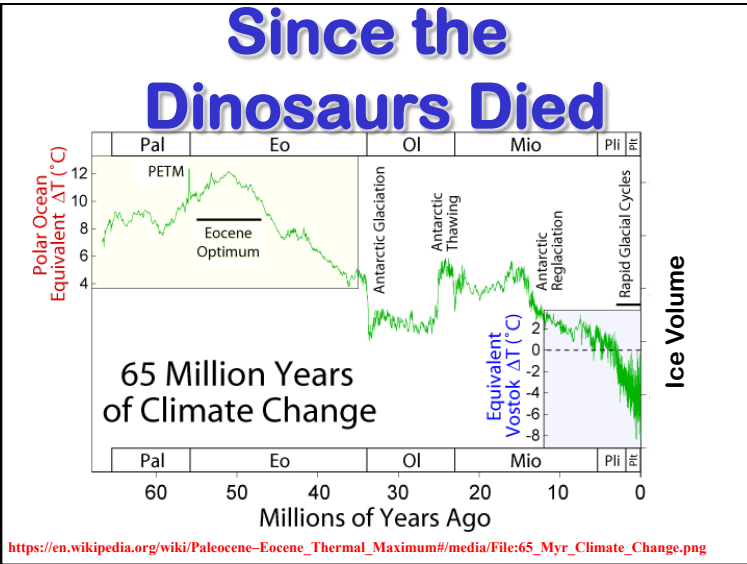
Permafrost

Hydrate stable

Methane emissions

Increased greenhouse warming and CO<sub>2</sub> formation from methane

Increased warming of the tundra surface (permafrost areas) and some ocean waters causes increased methane emissions

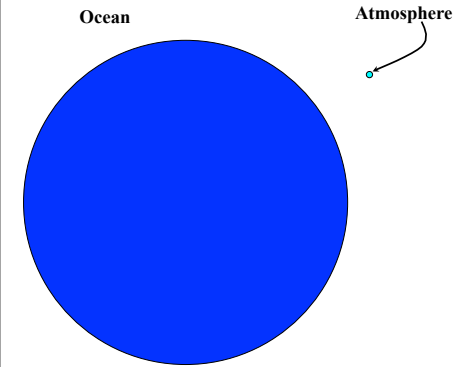


## Rise of Mammals

- While dinosaurs roamed, mammals were small, quick, & stealthy
- While the lizard's away, the mice will play!



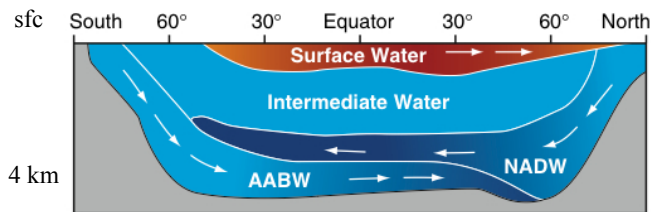
## Energy Reservoirs



- The oceans are about 4000 m deep
- The top 10 m equal the mass of the atmosphere
- The top 3 m equal the heat capacity of the atmosphere!

*The state of the oceans determines the climate on time scales of thousands to millions of years!*

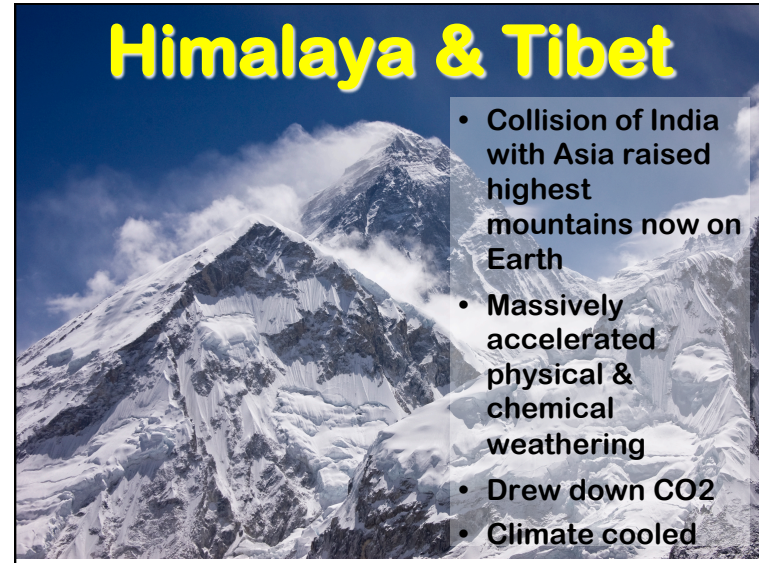
## Davy Jones Locker!



- Increased nutrients & dissolved CO<sub>2</sub>
- Warm, low nutrients, & oxygenated

- Warm buoyant "raft" floats at surface
- Cold deep water is only "formed" at high latitudes
- Very stable, hard to mix, takes ~ 1000 years!
- Icy cold, inky black, most of the ocean doesn't know we're here yet!

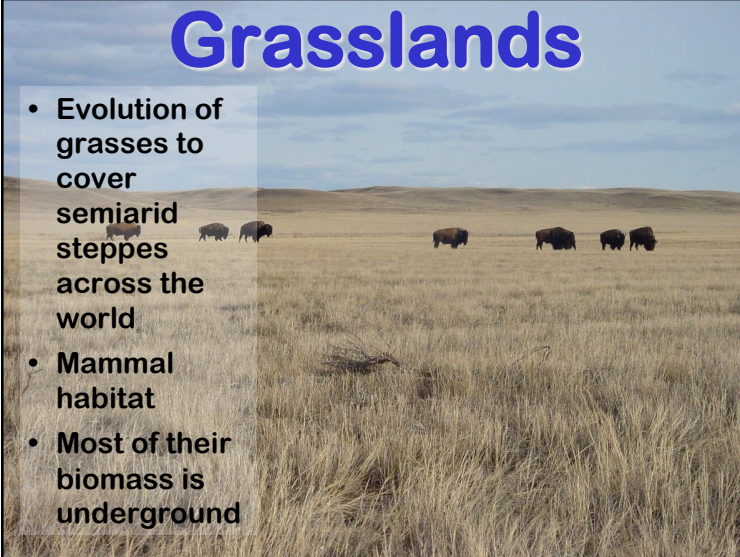
## Himalaya & Tibet



- Collision of India with Asia raised highest mountains now on Earth
- Massively accelerated physical & chemical weathering
- Drew down CO<sub>2</sub>
- Climate cooled


## Grasslands

- Evolution of grasses to cover semiarid steppes across the world
- Mammal habitat
- Most of their biomass is underground



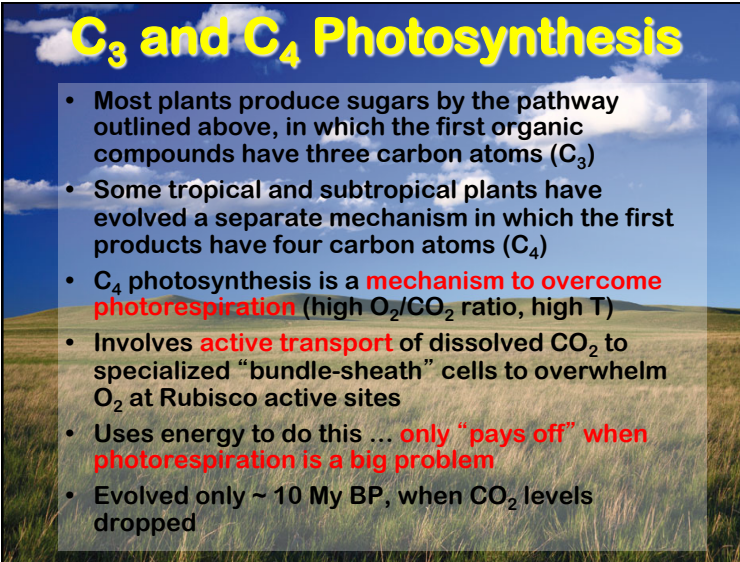
## Cenozoic Climates (since 65 Ma)

- Gradual **global cooling**
- **India collided with Asia, raised Tibet & Himalaya, rapid weathering**
- **Antarctica moved into polar position**
- Opening of Drake Passage initiated **Circumpolar Current** in the Southern Ocean
- Ocean surface and bottom temperatures **cooled by 10° C**
- Ice sheets in East Antarctica ~34 Ma, melting ~ 24 Ma
- **Northern Hemisphere ice sheets appeared about 3 Ma**



## C<sub>3</sub> and C<sub>4</sub> Photosynthesis

- Most plants produce sugars by the pathway outlined above, in which the first organic compounds have three carbon atoms (C<sub>3</sub>)
- Some tropical and subtropical plants have evolved a separate mechanism in which the first products have four carbon atoms (C<sub>4</sub>)
- C<sub>4</sub> photosynthesis is a **mechanism to overcome photorespiration** (high O<sub>2</sub>/CO<sub>2</sub> ratio, high T)
- Involves **active transport** of dissolved CO<sub>2</sub> to specialized “bundle-sheath” cells to overwhelm O<sub>2</sub> at Rubisco active sites
- Uses energy to do this ... **only “pays off” when photorespiration is a big problem**
- Evolved only ~ 10 My BP, when CO<sub>2</sub> levels dropped



## C<sub>3</sub> and C<sub>4</sub> Physiology & Biochemistry

