ATOC 1060-002
OUR CHANGING ENVIRONMENT
Lecture 21 (Chp 12)

Objectives of Today's Class

The long-term climate record

Announcements:

1. The Project; HW3;
2. Review session for the final exam: Dec 7th. Sean Haney;
3. Online FCQ: Nov 24-Dec 6 (FCQ.Office@Colorado.EDU).

Previous class: long-term climate records (tillites, dropstone, glacial striation-b.y.; fossil data and oxygen isotope-m.y.) indicate that:

Show movie: plucking; formation of terminal moraine;

The Earth climate: longer periods of warmth were separated by short, intense, glacial periods (sometimes, snowball Earth).

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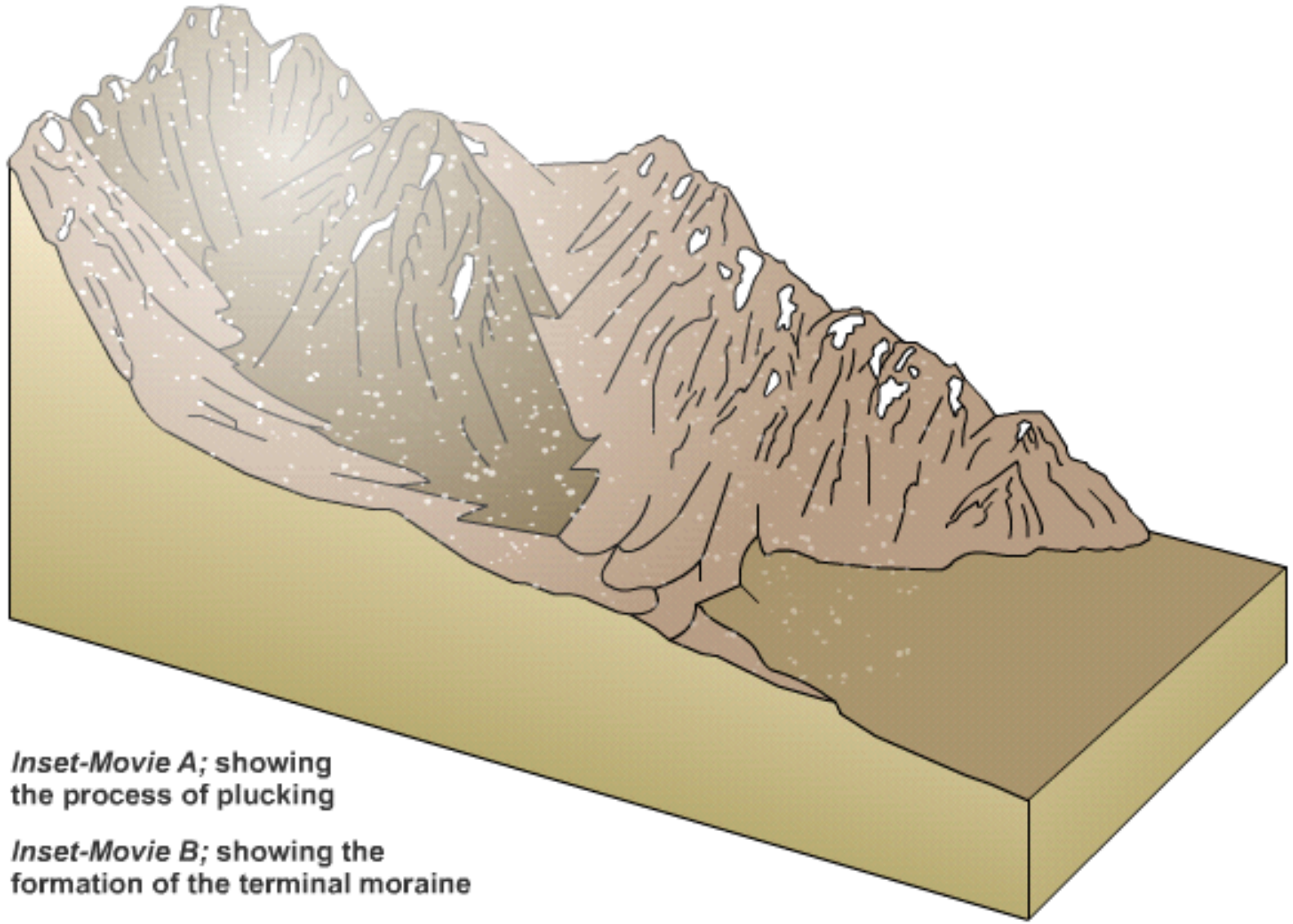


Inset-Movie A; showing the process of plucking

Inset-Movie B; showing the formation of the terminal moraine

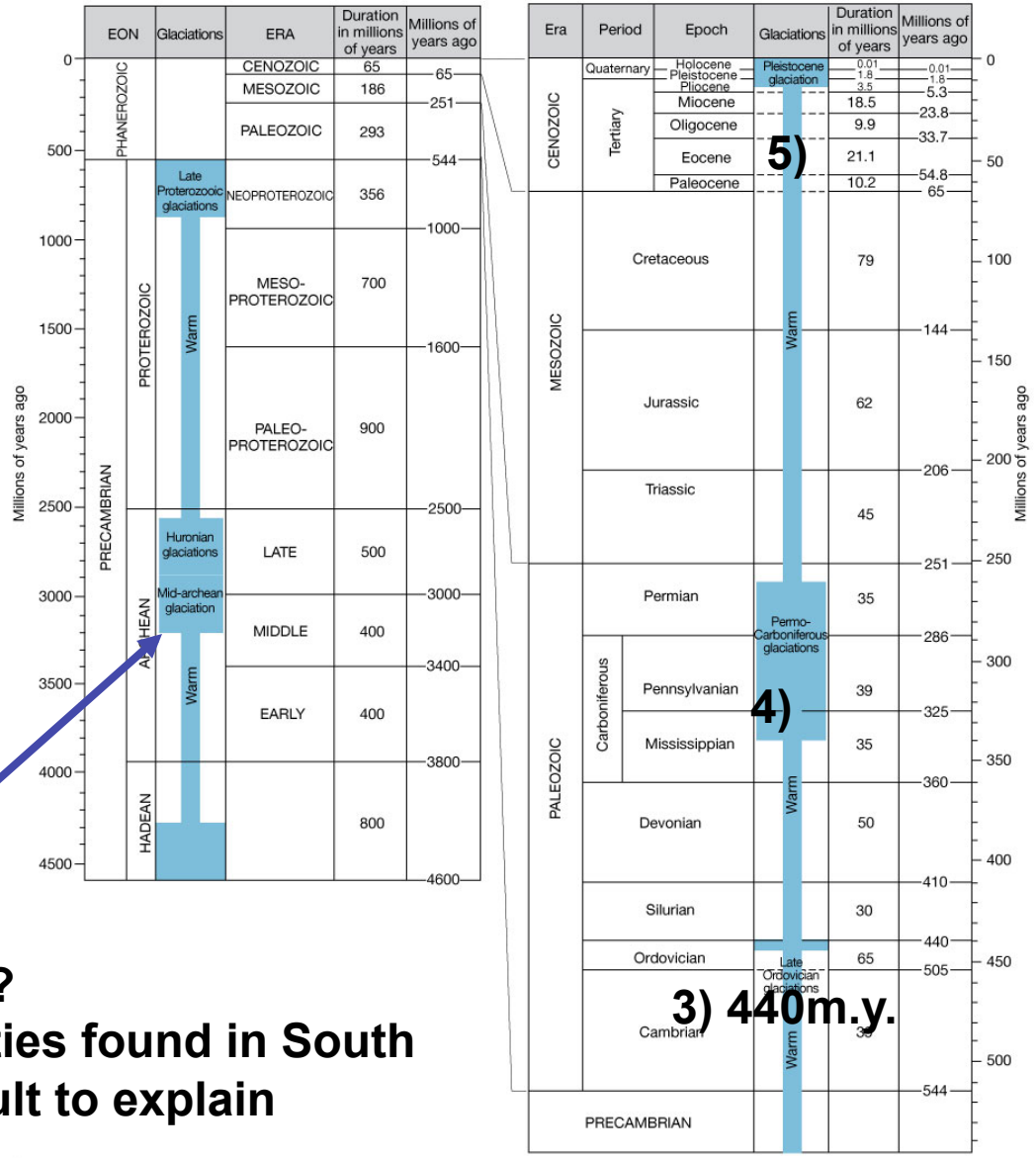
The long-term glacial record

Snowball

2) 600-800m.

Geologists: Earth's climate history: glacial Periods;

1) 2.3b



0) 2.9m.y. Mid-archean? Only 2 localities found in South Africa; difficult to explain

Fig 12-8

Snowball earth: The continents reconstruction at Late proterozoic: tillites, striation, dropstone

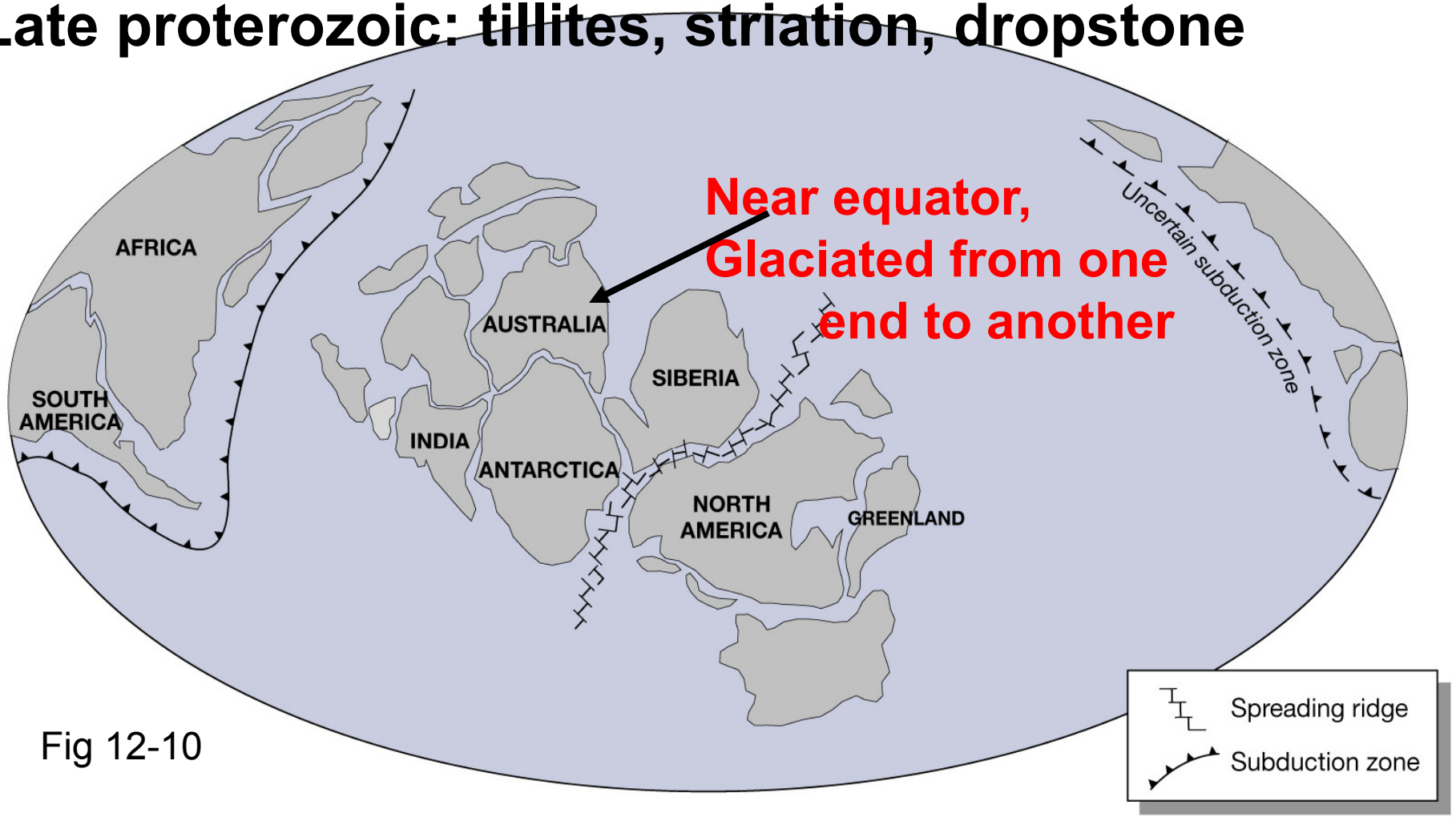


Fig 12-10

1. Large continent – enhance silicate weathering – remove CO2;
2. High temperature near the Equator – enhance silicate weathering
   - result in cold temperature, snowball

Clicker question 1

Choose the correct and most complete statement:

A. Geological evidence of past glaciation on billions of years timescales can be found in Tillites, dropstone and glacial striations;

B. Geological evidence indicates that throughout the Earth's history, the Earth's surface has had long periods of warming separated by short, intense periods of cooling;

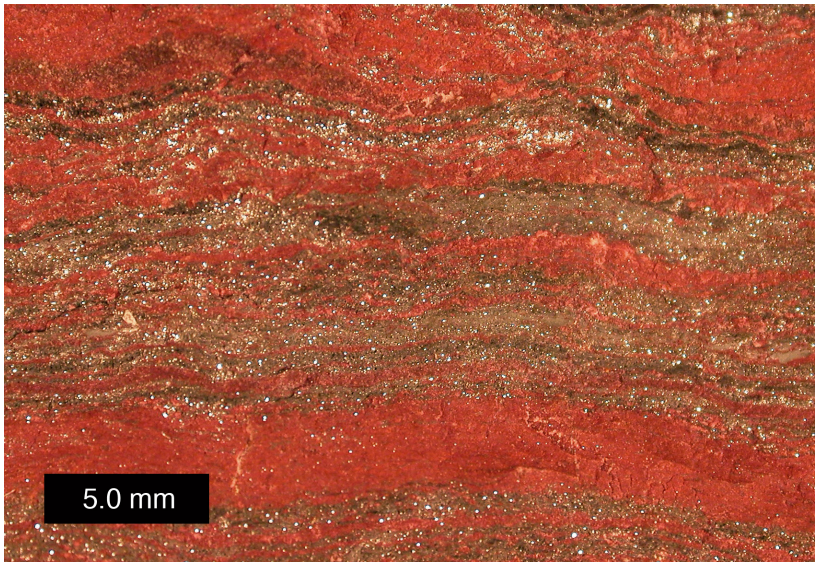
C. Geological evidence indicates that snowball Earth might have occurred 600-800 m.y. ago;

D. The snowball Earth likely resulted from enhanced silicate weathering due to large continent near the equator, which effectively removed CO_2 from the atmosphere;

E. All of above.

Today: Additional geological evidence for the snowball Earth

[1]Banded iron-formations (BIFs): anoxic condition. Found in Neoproterozoic -exactly the Late Proterozoic glaciation period (600-800m.y.);



(**snowball, cut atmospheric O_2 - anoxic in deeper ocean**
-hydrothermal vents in
-mid-ocean ridges
- ferrous iron - accumulated
-& upwelled to continental shelves)

[2] Cap Carbonates: Geological records show - above glacial deposite layers in low latitude - 400m carbonate layer - fine grained (**quickly deposited aftermath of snowball Earth**).

Both BIF and Cap Carbonates => snowball Earth in Late Proterozoic (600-900m.y.ago)

Clicker question 2

Choose the correct and complete statement:

(A) BIFs and cap carbonate records indicate evidence of snowball earth;

(B) None of the geological records indicates that snowball earth has occurred;

(C) Various geological records indicate that snow ball earth occurred during the late proterozoic glaciation near 600-800m.y. ago;

(D) Both (A) and (C).

Climate during the Phanerozoic

Phanerozoic Eon- after Proterozoic Eon (Late proterozoic glaciation) - after 540m.y. snow ball;

Glaciations before 544m.y. ago:

- **(? Mid-Archaen 2.9b.y. ago;)**
- **Huronian 2.3b.y. ago;**
- **Late Proterozoic 600-800m.y. ago;**

3 occur in Phanerozoic Eon, after 544m.y.:

- **Late Ordovician glaciations (brief): 440m.y. ago;**
- **Permo-Carboniferous (long series) 280m.y. ago;**
- **Pleistocene (most recent) 1.8m.y.**

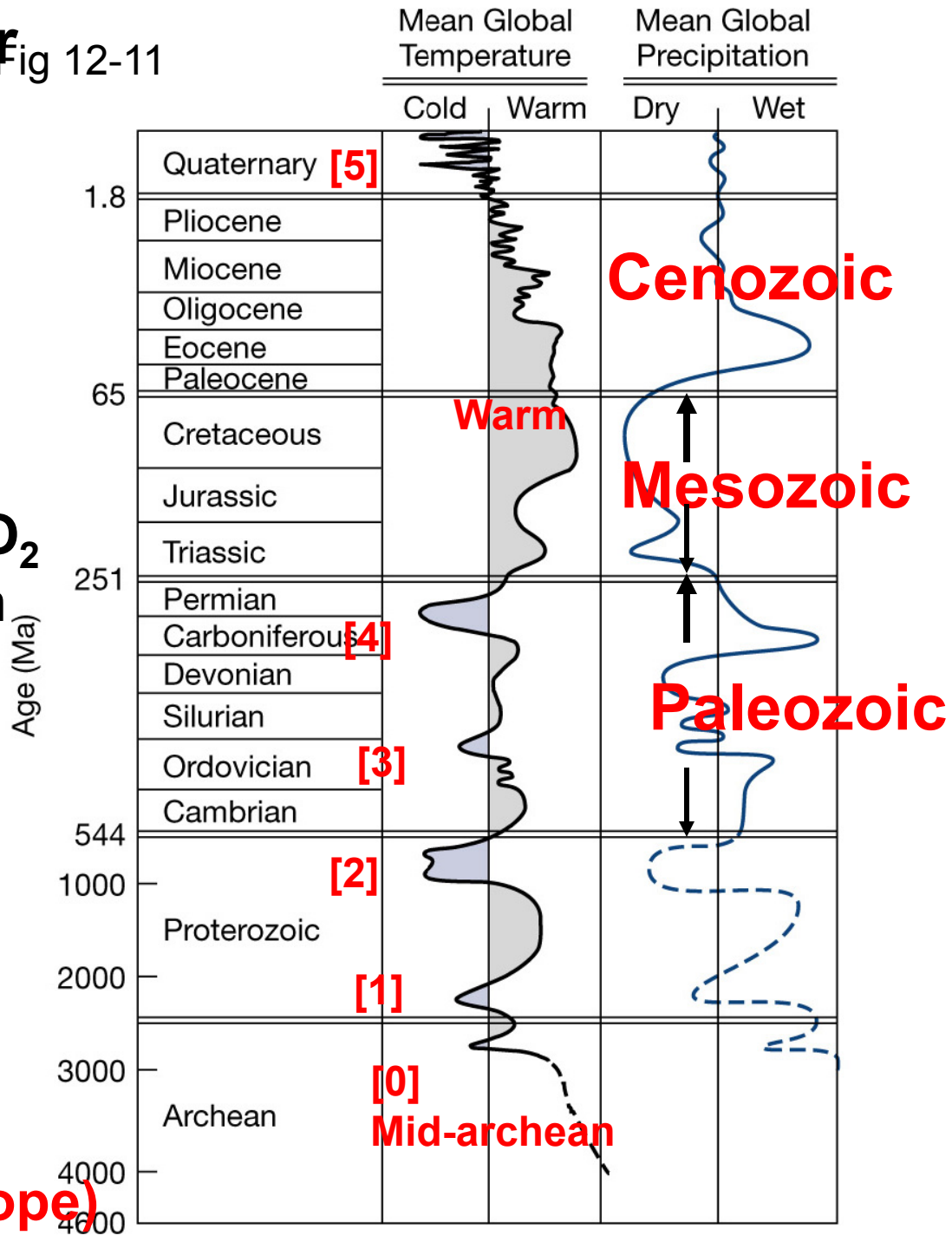
(glacial: maximum ice extent - doesn't need to be snowball)

Phanerozoic Eon (544m.y.-present) includes:
Paleozoic Era 544-251m.y. ago;
Mesozoic Era 251-65m.y. ago;
Cenozoic Era 65m.y. ago-recent.

Fossil records are available - climate change; scientists deduce climate: warm, cold, wet, dry - how much it varied from pole to equator.

(long timescales- solar Luminosity & greenhouse effect)

Fig 12-11



Continents move to equator - increase silicate weathering; Vascular plants reduce CO_2 - increase organic carbon burial rate [4];

Mesozoic & Cenozoic Era (past 251 m.y.):
Mesozoic: warm
2-6C warmer than today at equator;
20-60C warmer at Poles (fossil, oxygen isotope)

Estimated temperature limit during mid-Cretaceous (100m.y. ago)

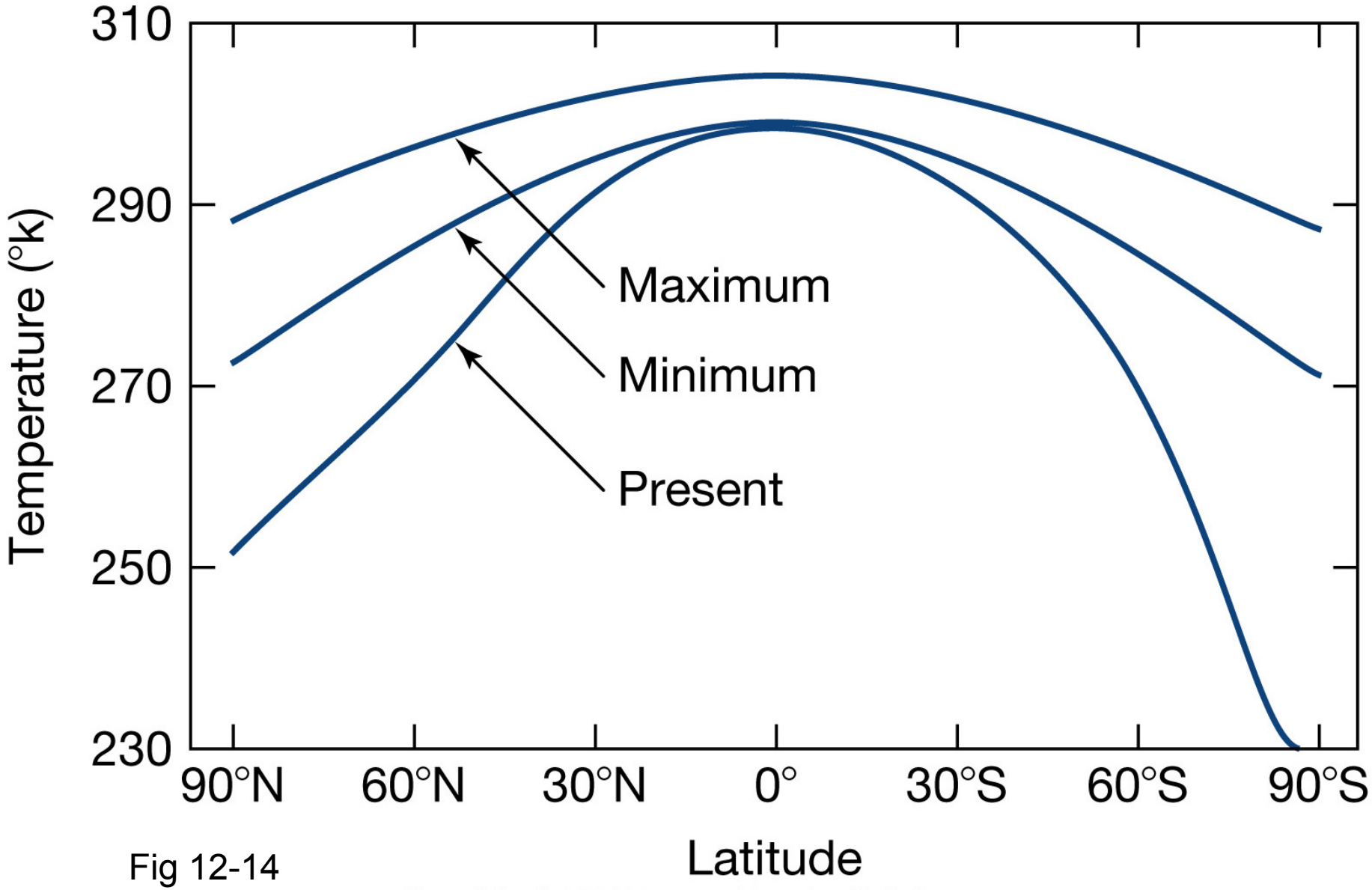


Fig 12-14

Clicker question 3

Choose the correct and complete statement:

A. The mesozoic Era is warm and dry;

B. The mesozoic Era is cold and wet;

C. During mesozoic Era, polar to equator Temperature contrast is higher than it is Today;

D. During mesozoic Era, polar to equator Temperature contrast is lower than it is Today.

E. Both A and D.

Warm Mesozoic: increased level of **CO_2**

[a] Enhanced volcanic eruption;
[b] Increased sea level reduce area of continents - Reduce silicate weathering rate;
[c] Faster sea floor spreading - faster subduction of carbonate sediments - faster CO_2 production of carbonate metamorphism.

Carbon isotopic evidence of high mesozoic CO_2 levels

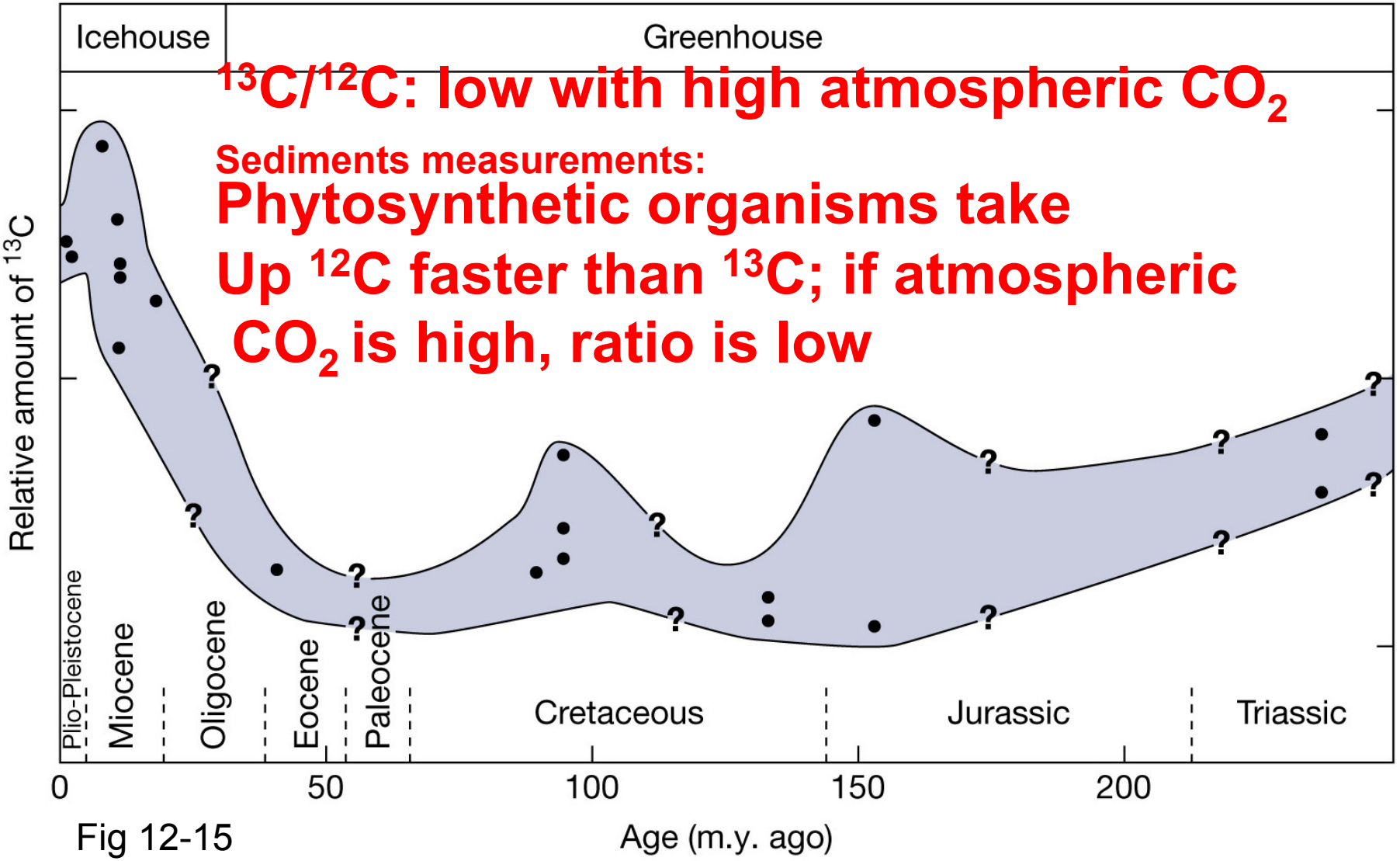


Fig 12-15

Other possible influences on mesozoic warming

Temperature contrast between Equator and Pole:

Mid-cretaceous: 20-30^{o}C;

Today: 50-60^{o}C;

Partial reason: removal of polar ice in mid-cretaceous (positive feedback);

Not enough!

Heat transport more efficient in mesozoic- the thermohaline circulation?

Hadley cells extend further poleward than today

Clicker question 4

Choose the correct statement:

(A)The warm mesozoic resulted mainly from the high concentration of atmospheric CO_2;

(B)The warm mesozoic resulted mainly from the high concentration of atmospheric CH_4;

(C)The low polar-equator temperature contrast in mesozoic resulted partly from polarward extension of Hadley cell.

(D) Both (A) and (C).

Cooling during the cenozoic Era

Cooling began about 80m.y. ago.
Initial cooling: reduced mid-ocean ridge spreading rates (spreading data) => reduce carbonate metamorphism => reduce atmospheric CO_2;

Accelerated cooling around 30m.y. ago does not agree with mid-ocean ridge spreading data;

Silicate weathering - enhanced by plate tectonics => see below.

India is separated from Asia

60 m.y. ago

40 m.y. ago

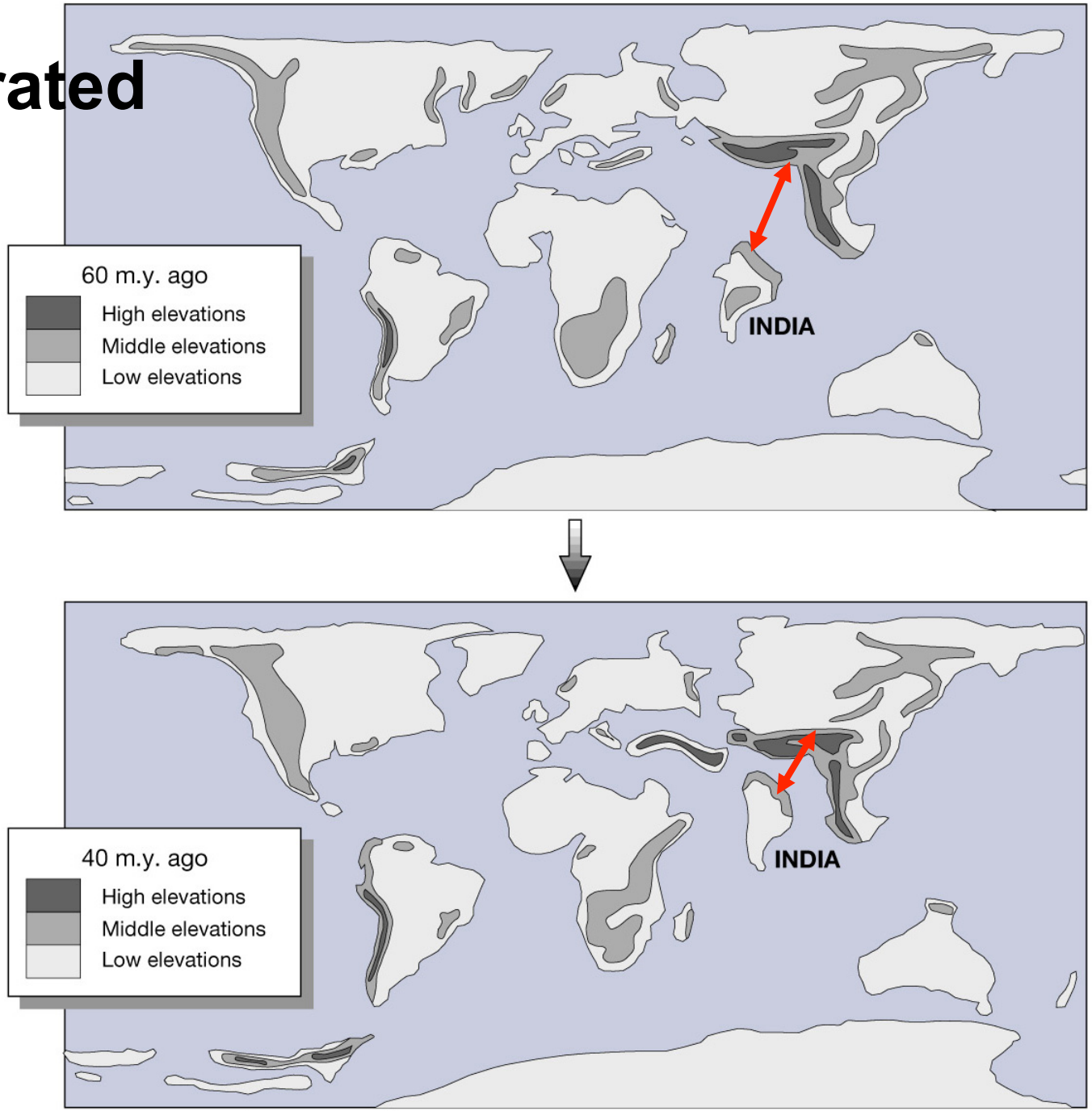
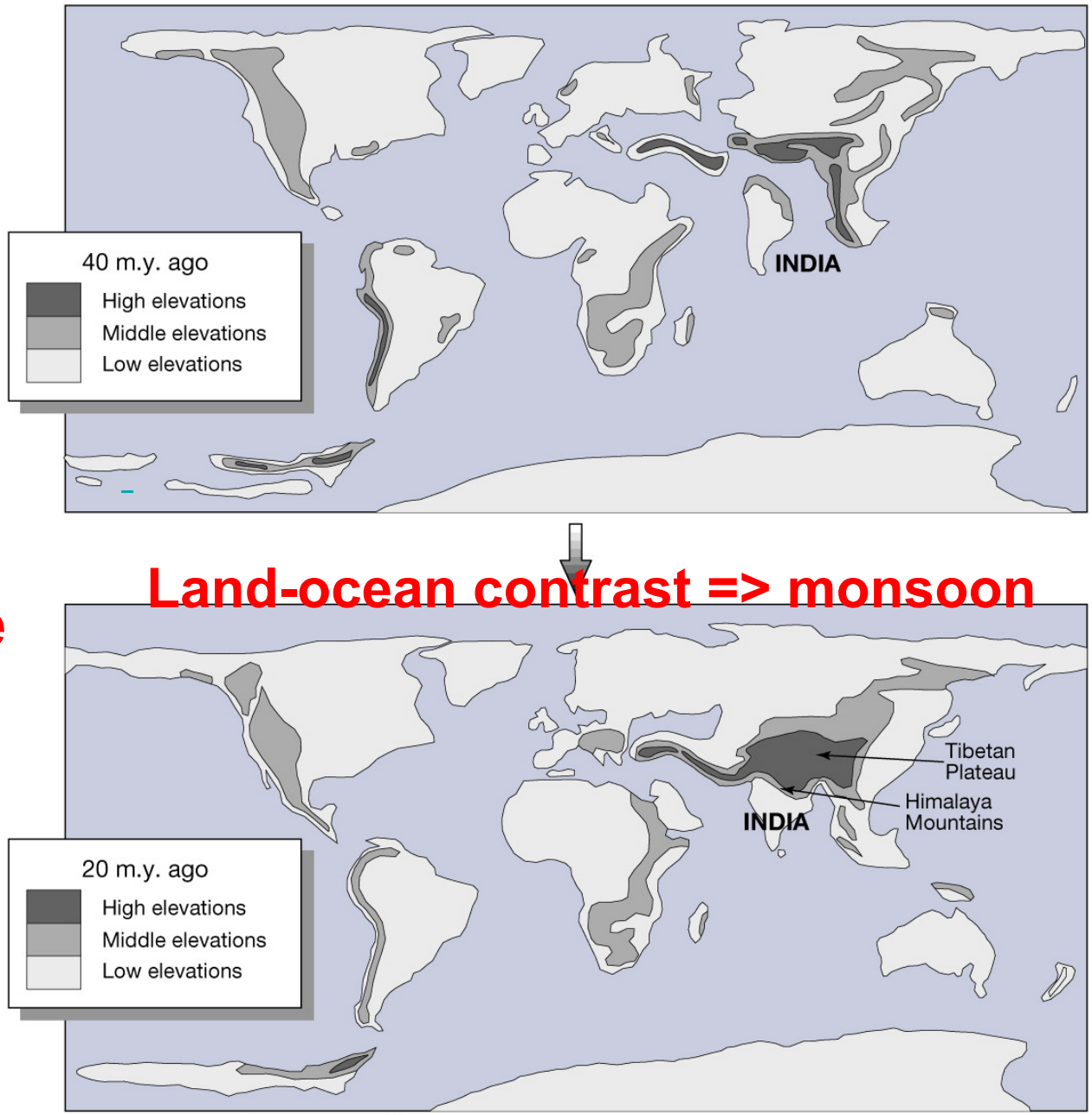


Fig 12-16

(40 m.y. ago)



[1]Large land - Enhace silicate weathering

[2]Monsoon Rainfall - Weathering

(20 m.y. ago)

Fig 12-16

Clicker question 5

Choose the right statement:

(A)Cooling of Cenozoic resulted mainly from reduced concentration of atmospheric CH_4;

(B) The merge of India with Asian continent accelerated the cooling near 30 m.y. ago by enhancing silicate weathering;

(C) The merge of India with Asian continent accelerated the cooling near 30 m.y. ago by reducing monsoon rainfall.

(D) None of the above.