ATOC 1060-002
OUR CHANGING ENVIRONMENT

Class 20 (Chp 12)

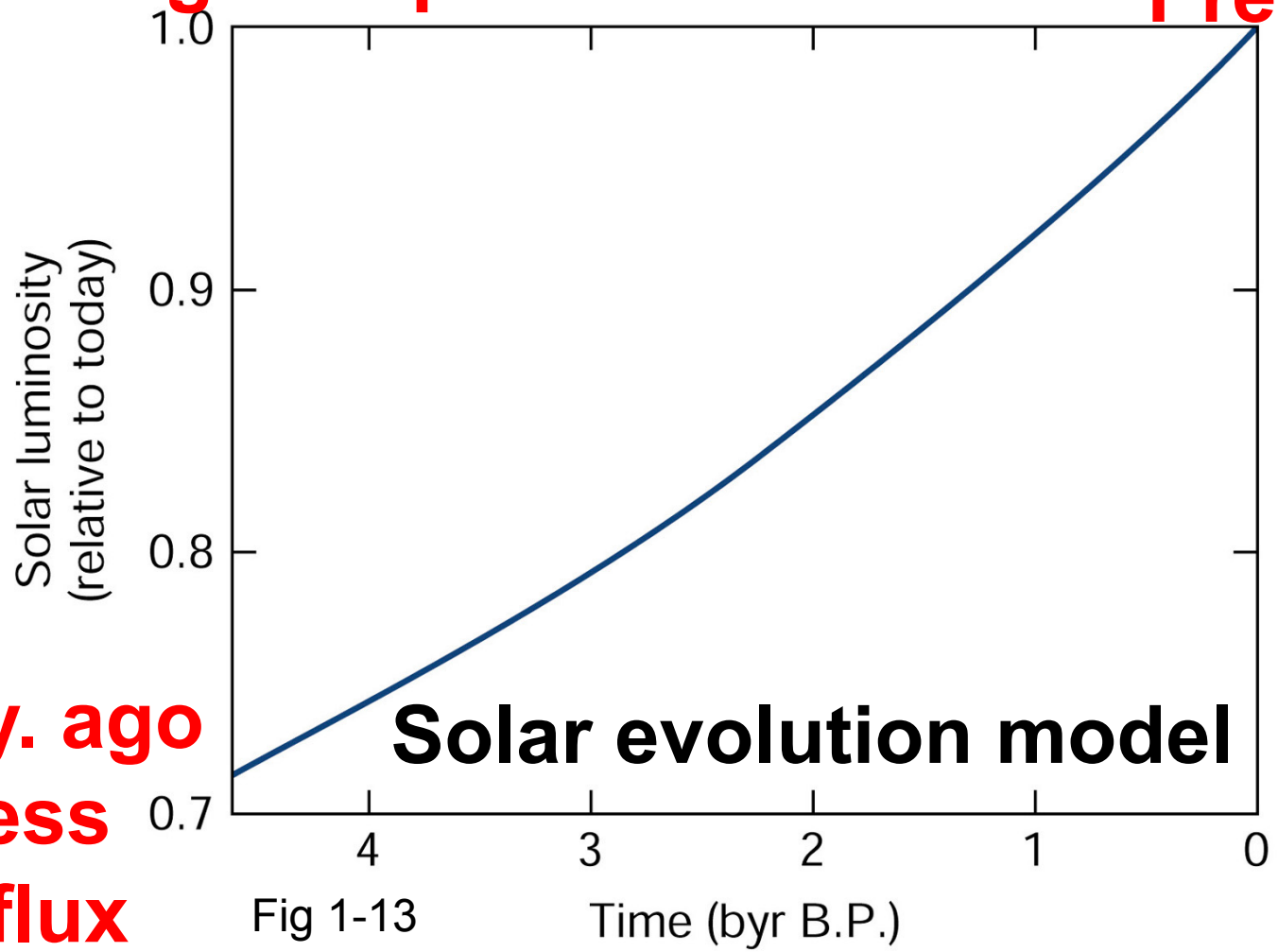
Objectives of Today's Class:

1. The long-term climate regulation;
2. The long-term climate record.

1. Long-term climate regulation

Faint Young Sun paradox:

Present



4.6 b.y. ago

30% less solar flux

Fig 1-13

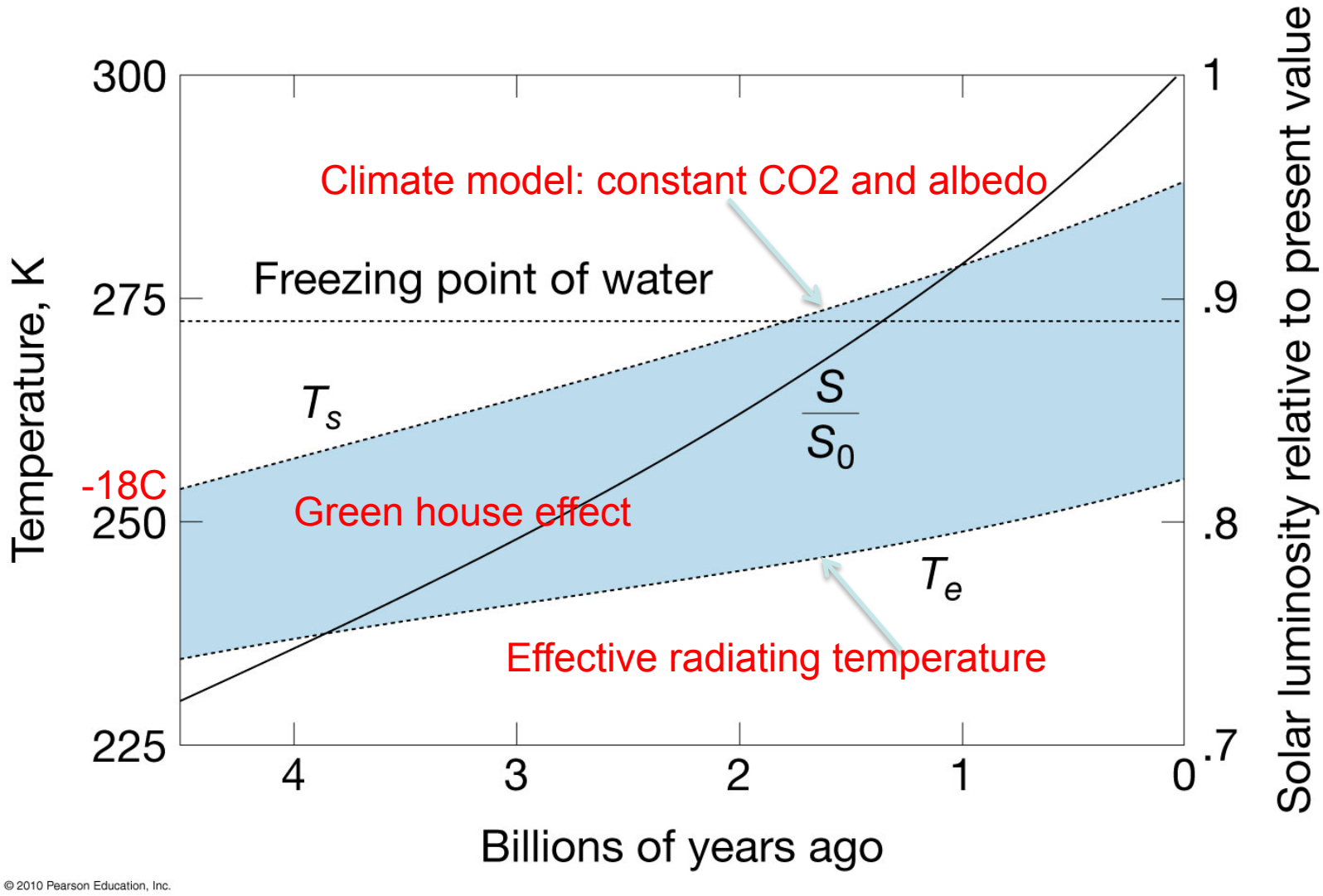


Fig. 12-2

Below freezing: 1.9b.y. ago => contradict geological evidence: liquid water was present 3.8b.y. ago!

The earth was warmer than predicted by the fain young sun!

Possible solutions:

i. Lower planetary albedo in the past (0?);

ii. Additional heat sources besides the Sun (geothermal heat) – too small;

iii. Larger greenhouse effect.

Clicker question 1

The most likely solution to the faint young Sun Paradox is:

A. The lower albedo of early Earth;
B. More geothermal heat of early Earth;
C. Larger concentrations of greenhouse gases in the atmosphere of early Earth;
D. Both A and B.

iii: Larger greenhouse effects (most likely): CO_2&CH_4

Young Earth, Higher CO_2: Impact Degassing (carbonate rocks);
Smaller Continents => reduce carbonate rocks storage, reduce silicate rocks weathering=>increase atmospheric CO_2;

[Silicate weathering (example): remove atmosphere CO_2:
$CaSiO_3 + 2H_2CO_3 => Ca^{2+} + 2HCO_3^- + SiO_2 + H_2O$]
Wollastonite **bicarbonate ion** **silica**

CO_2 dissolve in raindrops (acid)

Silicate weathering process: proportional to temperature;

Models: Methane 1000ppm (600times of today, 1.6ppm), 3.8-2.3b.y. ago: Archean Eon (when O_2 levels low)

Favor production of **CH_4 (by methanogens)**

A pink sky during Archean?

The Earth: blue sky **The Mars larger particles**

Scattering blue lights: O_2,N_2
Archean: CH_4 & CO_2, polymerize=> bigger long-chains=>scattering orange,red light;

A pink sky during Archean?

The Earth: blue sky

The Mars: pink (red);

Scattering blue lights: O_2,N_2

Archean: CH_4 & CO_2, polymerize=> bigger long-chains (haze) => scattering orange,red light;

Clicker question 2

A. Early earth has higher CO2 concentration possibly because young earth can be degassed by more meteorite, etc;

B. Early earth has higher CO2 concentration because young earth had smaller land area, and thus reduced silicate weathering;

C. Early earth has more methane concentration because of its low oxygen level;

D. All of the above.

Climate regulation by the anti-greenhouse effect

Was the Earth getting hotter and hotter until no life could survive? NO.

Anti-greenhouse effect:

CH_4 and haze: strong absorbers of visible (red) light and near-infrared => reradiating back into space without reaching the Earth's surface => cools Earth's surface.

If haze layer too thick =>

The Earth too cold

=> CH4 producing bacterial died off

=> reduce CH4

=> thinner haze layer

=> increase Temprature.

Regulating the climate in Archean Era.

Clicker question 3

A. The earth gets hotter and hotter due to Green house effects until no life can survive;

B. Methane haze has anti-green house effect to cool the Earth if it gets too hot;

c. The methane haze's anti-green house effect can continuously cool the Earth's surface without stopping;

D. All of the above.

2. The long-term climate record

Up to now: focus on very early Earth & processes may have contributed to climate stabilization.

Geological indicators=>paleoclimate (past climate) complex => long-term warmth periods & short, intense cold periods, there may have been "Snowball Earth" episodes => suggesting other factors may affect climate as well.

Paleoclimate:geological indicators

Recent Earth history (millions yrs): estimate ocean temperatures by oxygen isotopes in carbonate sediments from deep-sea cores.

More stable

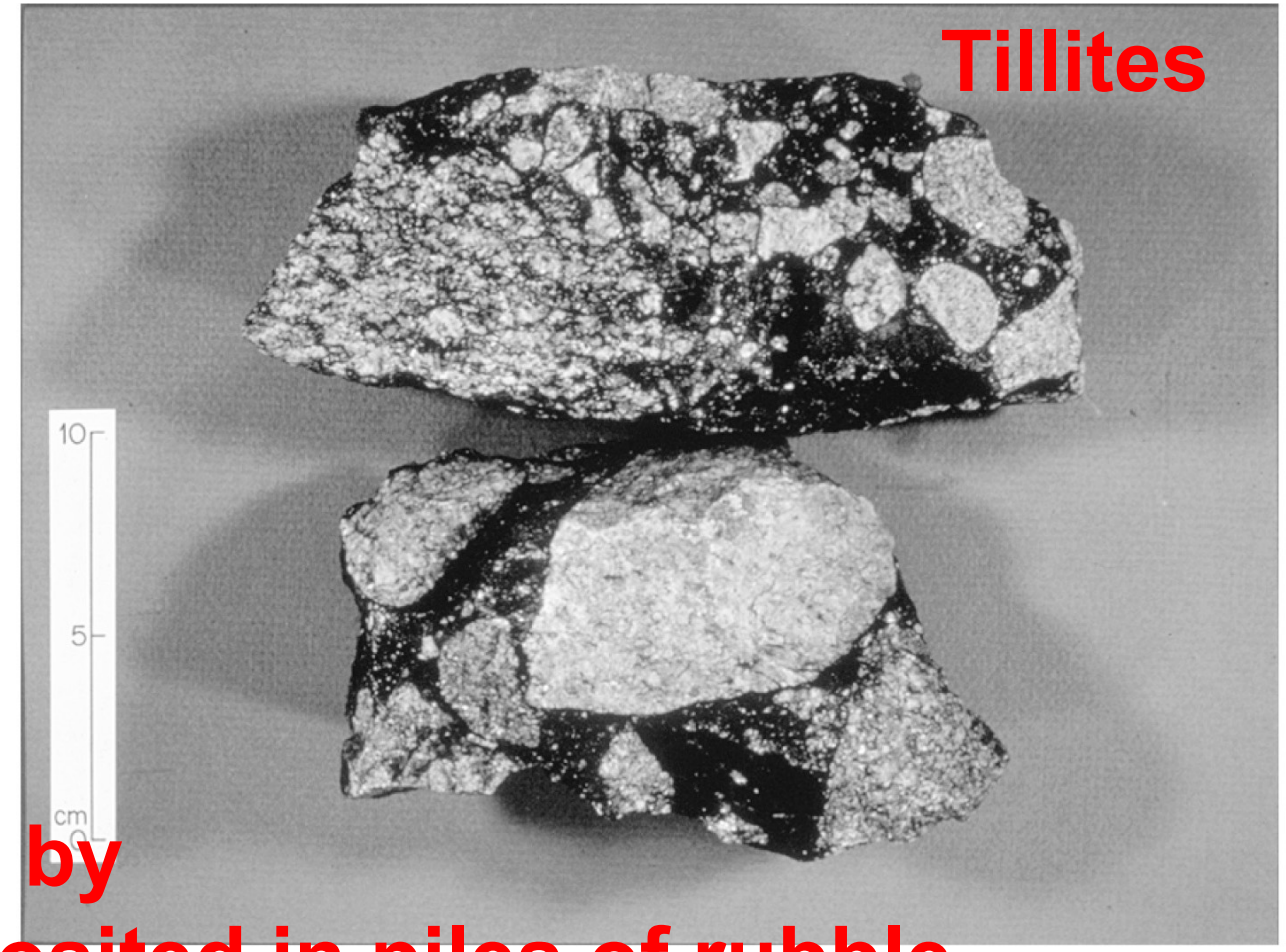
[1] C_aCO_3 => ^{16}O and ^{18}O; the colder the water, the more ^{18}O to be incorporated by minerals

$\Rightarrow$Glacial-interglacial cycles in about 200m.y;

[2] 540m.y. fossil record; species of plants and animals live in certain climates => estimate local surface temperature

Evidence of past glaciation

Billion-year timescale: Geologic deposit formed by glacial ice.



(a)

Fig 12-7a:

Debris when glaciers grind up surface rocks=>carried by glaciers & deposited in piles of rubble -moraines (icesheet margin)

Rocks with long, parallel scratches: glacial striations: moving glaciers drag other rocks across their surface

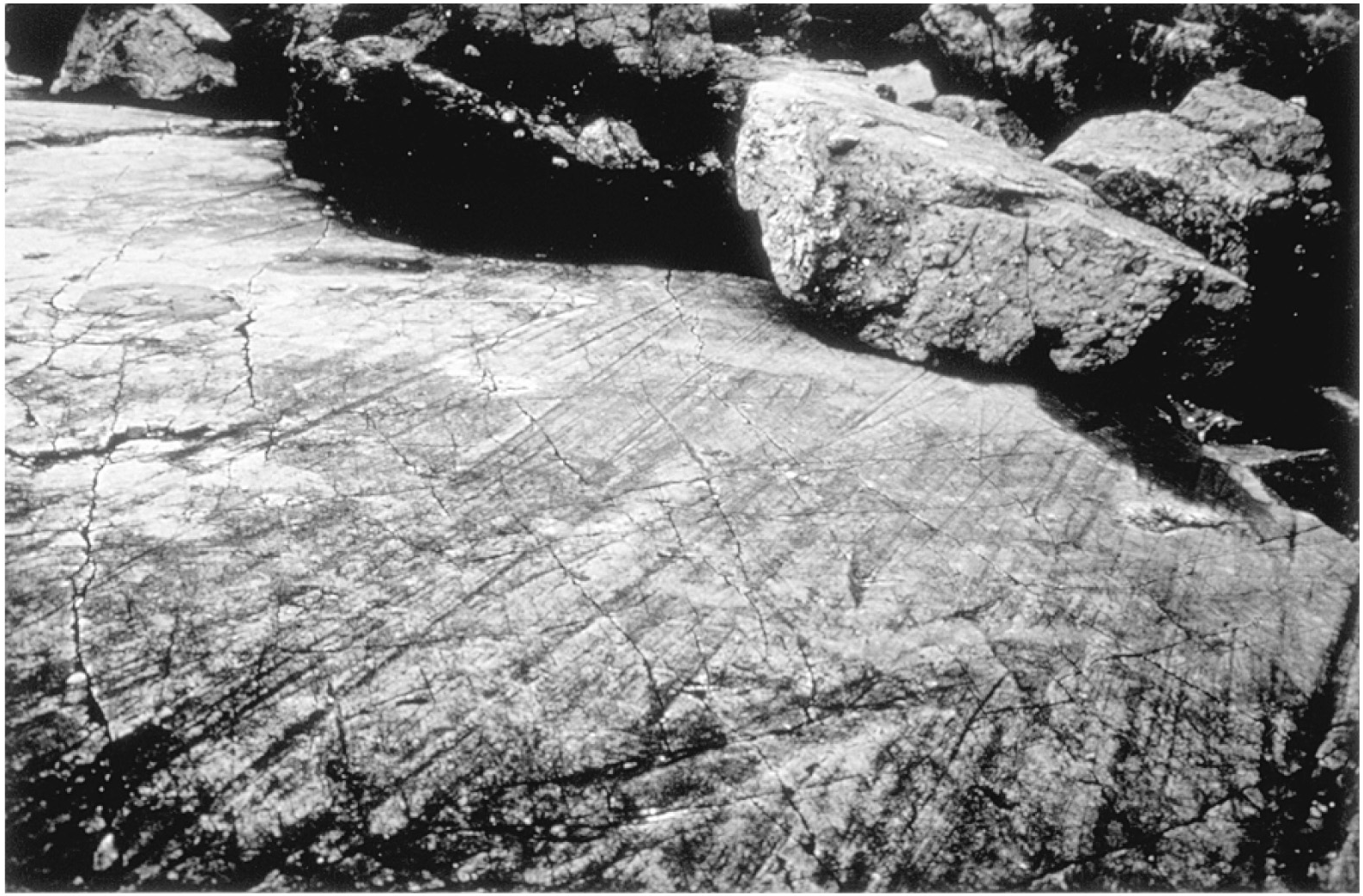


Fig 12-7b (b)

“Misplaced” trunks of rock in otherwise finely laminated marine sediments

Rocks Trapped In glacial Ice carried to sea by icebergs

Dropstone

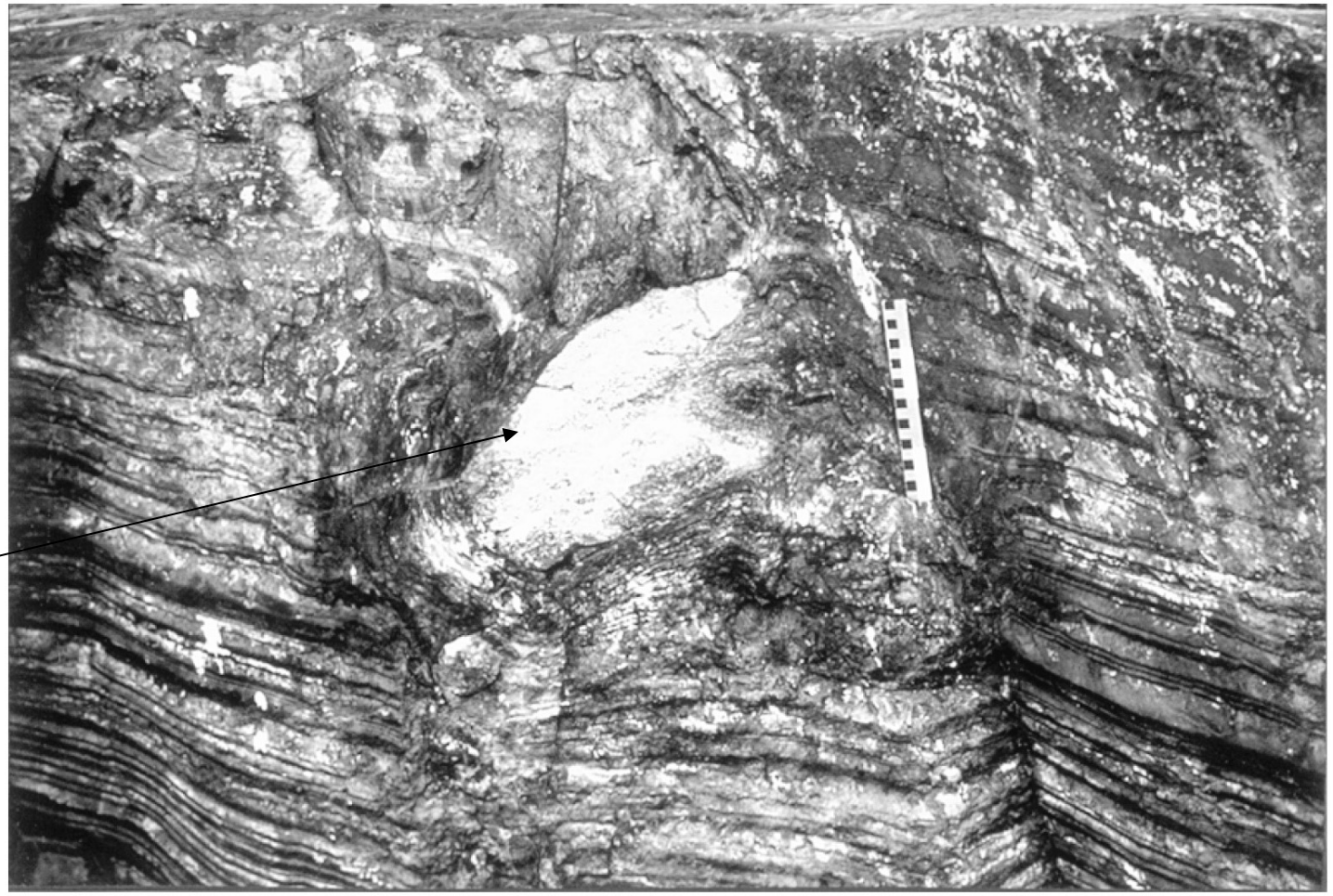


Fig 12-7c (c)

Clicker question 4

Geological evidence of past glaciation on billions of years timescale can be found in (only one most complete answer);

A.Tillites and glacial striations;

B. Dropstone;

C. Oxygen isotopes;

D. Both A and B.

The long-term glacial record

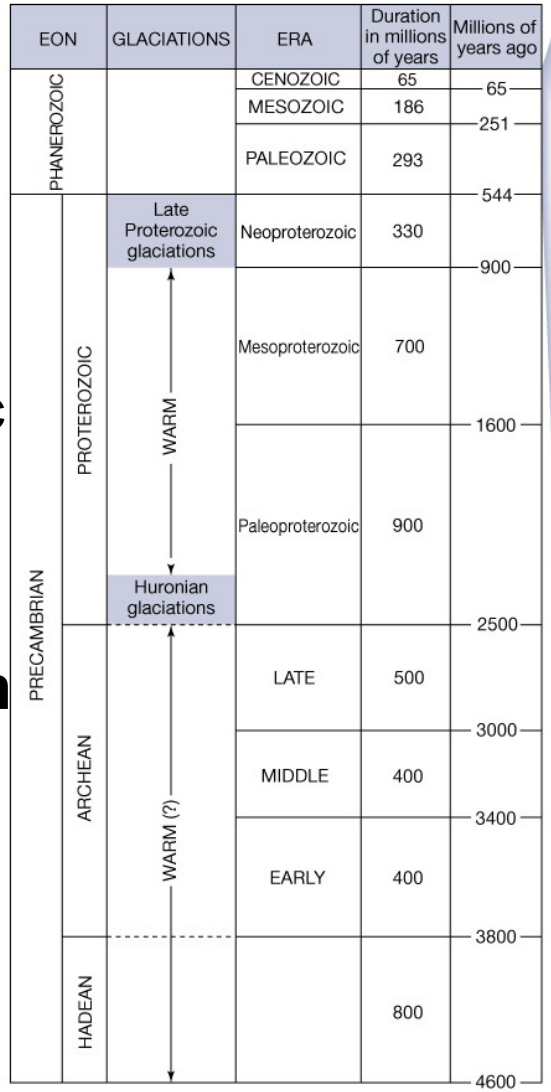
Geologists: Earth's climate history: 5 main glaciation periods.

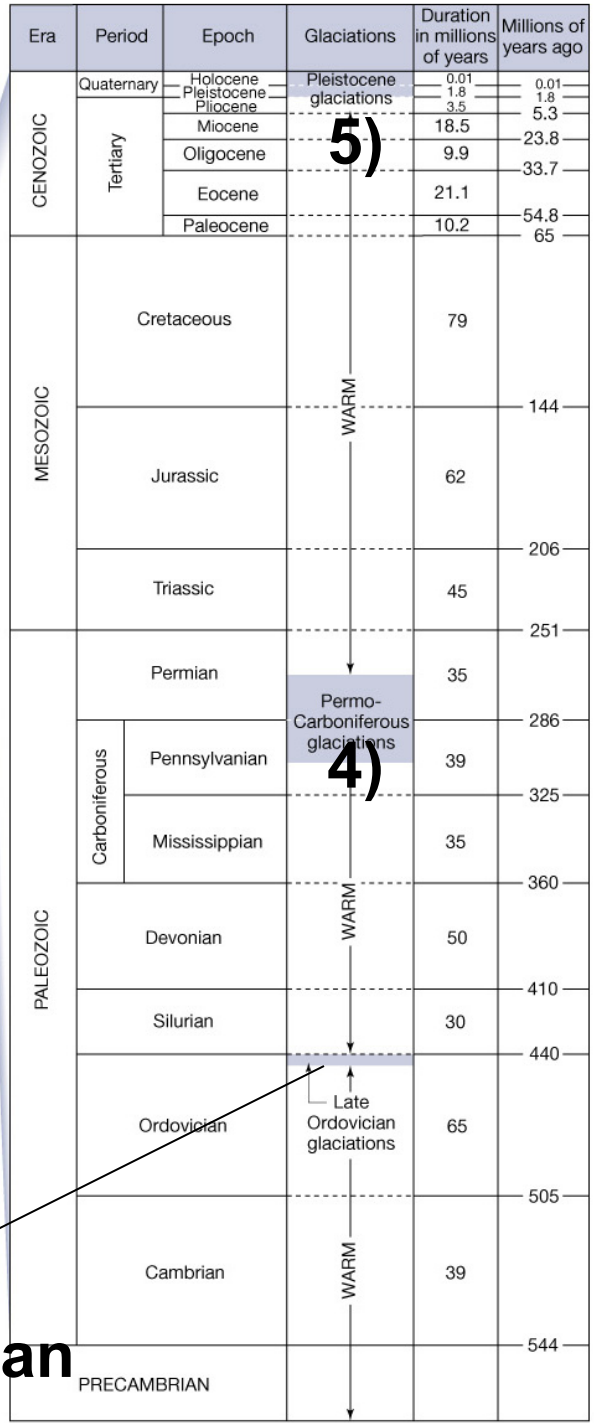
2) 600-800m.y. Late Proterozoic

1) 2.3b.y. Huronian

4) ~286m.y. Permo-Carboniferous

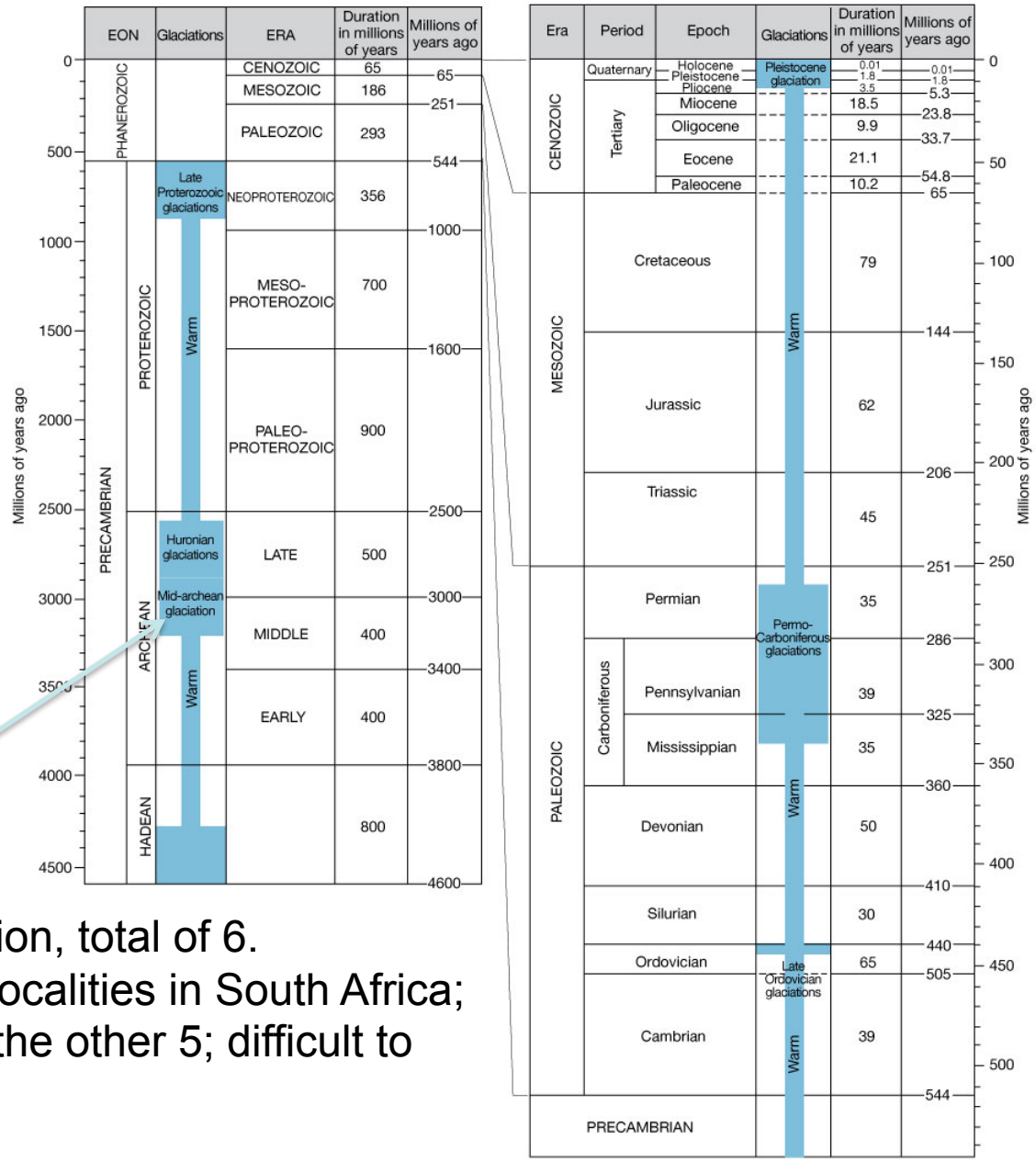
5) ~1.8-recent, Pleistocene





3) 440m.y. Late Ordovician

Textbook 2nd edition



Mid-archean glaciation, total of 6.
Known from only 2 localities in South Africa;
Not well studied as the other 5; difficult to Explain.

Textbook, 3rd edition.

2.3b.y. ago: derived by tillite & dropstone; First found in lake Huron (N. America) => Huronian glaciation. Followed by 1b.y. ice-free conditions.

Why was there a glaciation?

Suppose CH_4 was high in Late Archean (3-2.5b.y) => O_2 rise around 2.3b.y. due to biological activities (photosynthesis) => eliminate CH_4 => cold! (Geological evidences agree with this).

How did the Earth's temperature rise again?

Silicate weathering decreases with decrease of temperature => increase CO_2 => increase temperature.

Low-latitude glaciation: the snowball Earth

The climate became cool once again.
Glaciation in the Late Proterozoic (800-600 m.y. ago). [Rising CO_2 => increase Temperature=> increase silicate weathering => decrease CO_2 => cool the temperature.]

Geological evidence: tillites, glacial striations, dropstone were found on 6 of the 7 present day continents (except Antarctica, largely buried by ice);
=> Snowball Earth.

The continents reconstruction at Late proterozoic

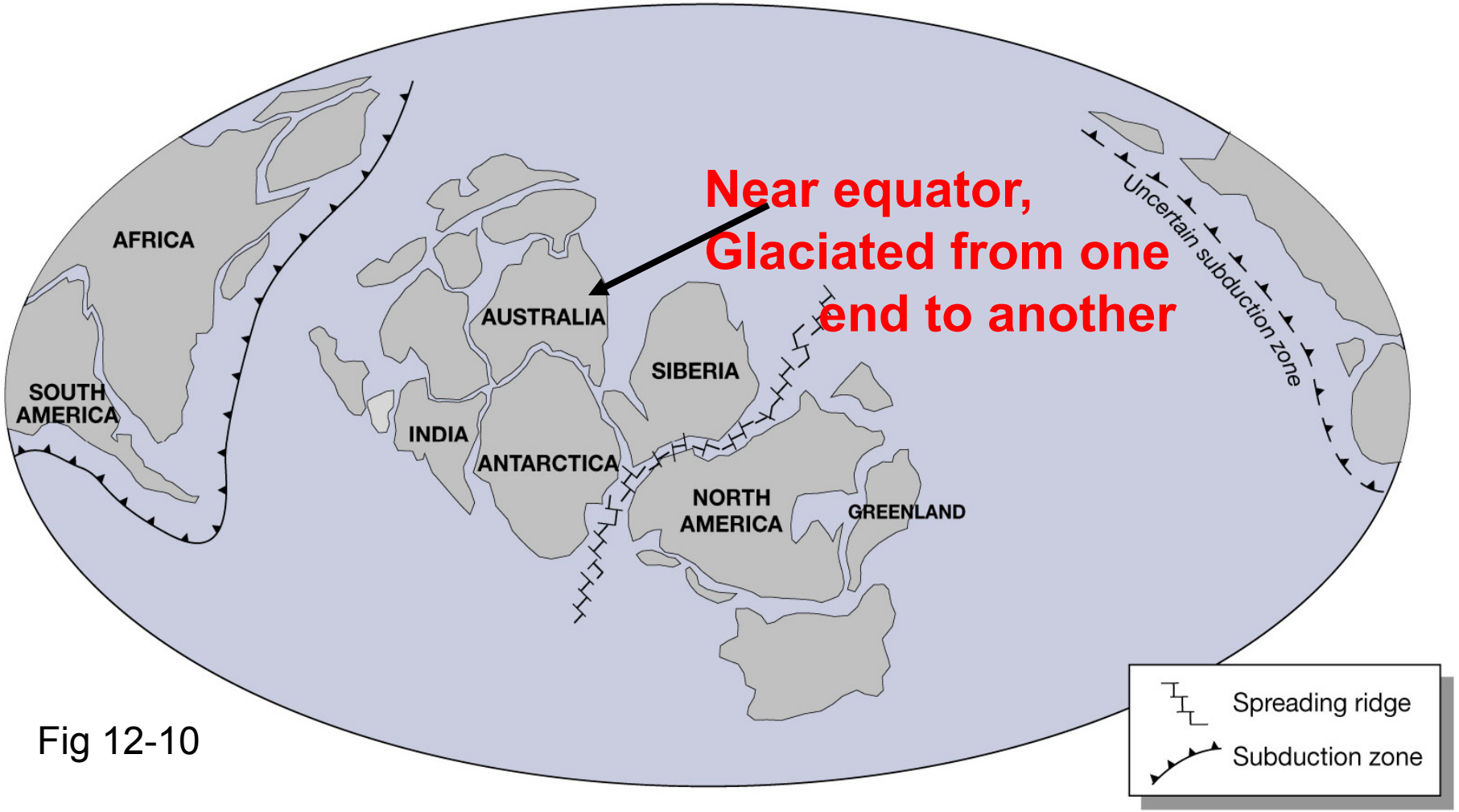


Fig 12-10

Today: tropical glaciation: confined to high mountains;
Example: Andes mountains in S. America, above 5km.
Geologists: convinced Late proterozoic glaciation is real - all data;

Clicker question 5

Geologists believe that throughout the Earth's climate history:

A. There were 5 major glaciation periods, and the Huron glaciation was the first;

B. There were 5 major glaciation periods, and the Late Proterozoic is the first;

C. There were 4 major glaciation periods;

D. There were 3 major glaciation periods.