Sea Level Change during Glacial cycles

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Question.

What happens to a planet when large ice sheets form or decay?

or:

How does the earth and the ocean respond to this?

If we can observe this response, what can we learn about the planet and the ice?

Can we answer:

- How thick was the ice?
- Was there any ice at all in some locations in the past?
- Were some ice sheets greater in the past than today?

If we can observe this response what can we learn about the planet and the ice?

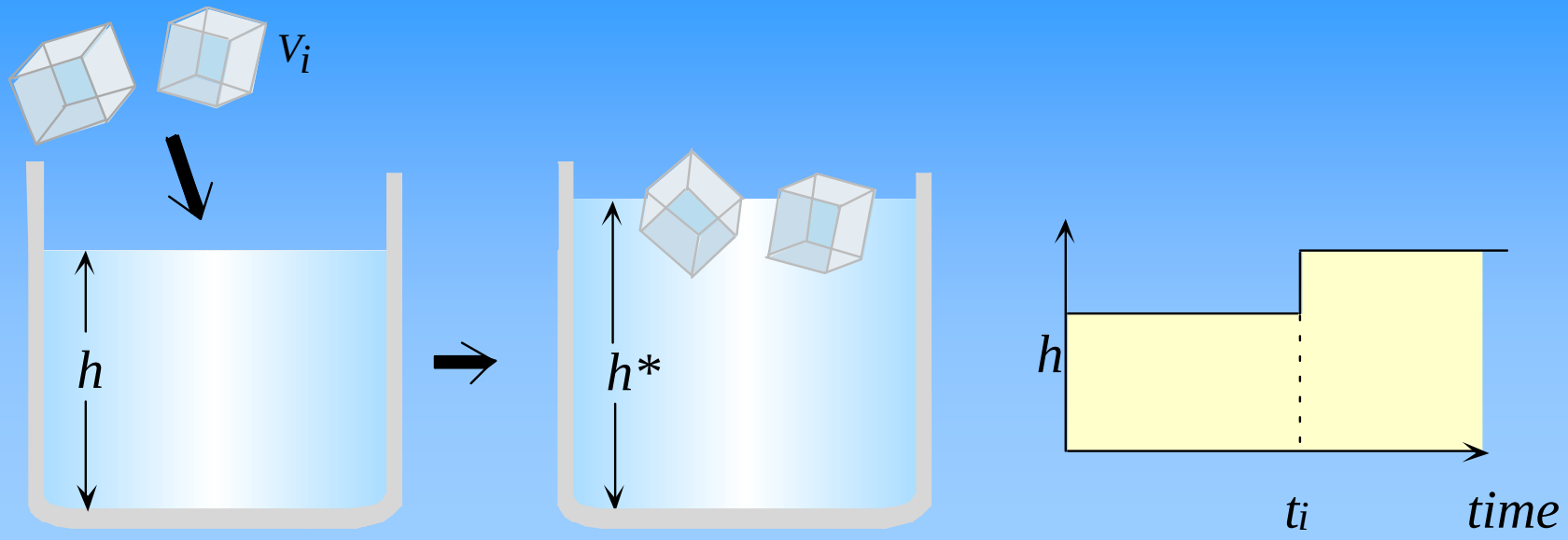
Can we answer?

What is the Earth's rheology?

What are its elastic and viscous properties?

Answer to Earth questions lead to constraints on:

- physical properties of the planet
- mantle convection (driving forces for plate tectonics).
- thermal history of the planet (on rates of heat transport out of the interior of the planet).



$$h = \frac{V_w}{A} \qquad h^* = (V_w + V_i \frac{\rho_w}{\rho_i})/A$$

Δh = change in water level = $h^* - h = \frac{V_i}{A} \frac{\rho_w}{\rho_i}$

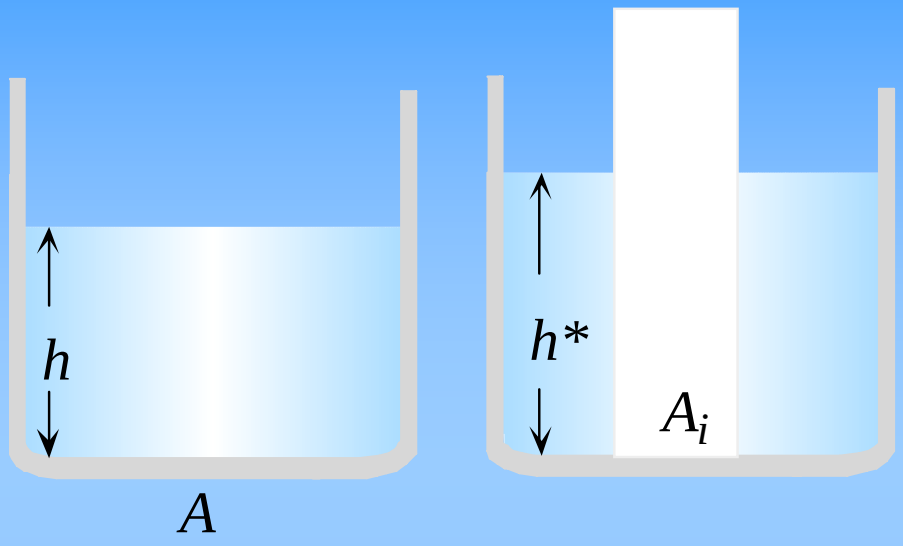
ρ_w = density of water

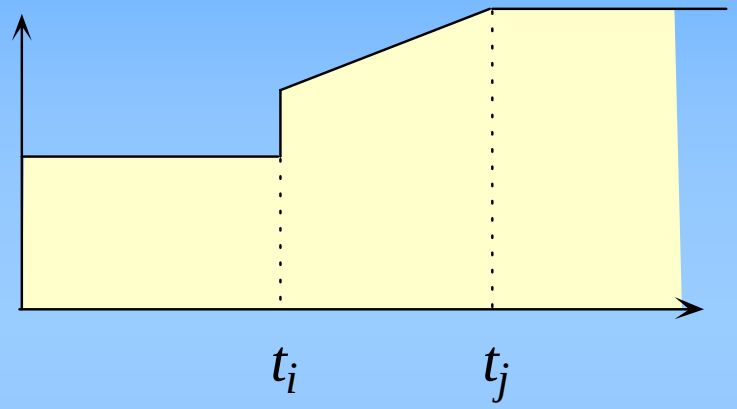
ρ_i = density of ice

A = area of water surface

V_i = volume of ice added

V_w = volume of water





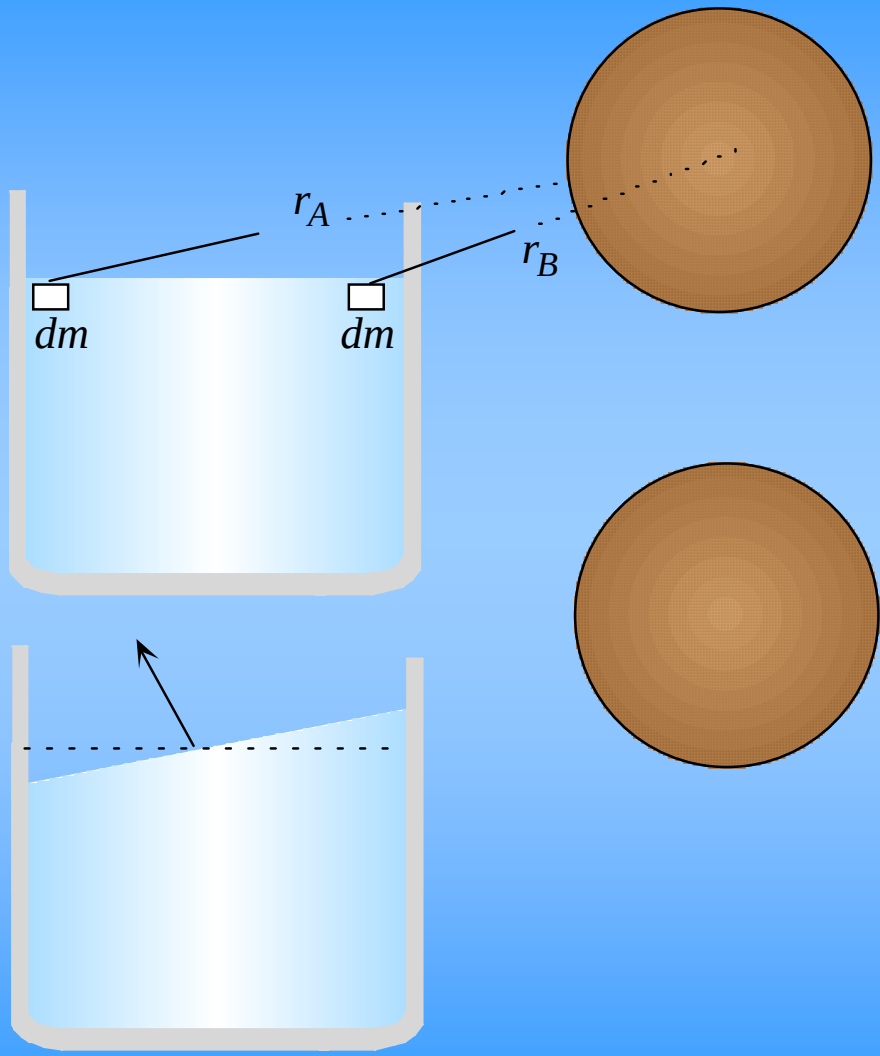
$$\Delta h = h^* - h = \frac{hA_i}{A - A_i}$$

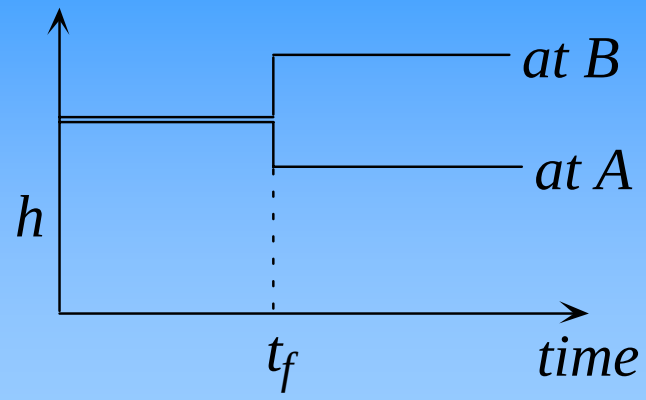
A_i = *area of ice collumn*

(The volume of water hA is squeezed into smaller space of surface area $A - A_i$*)*

t_i = *time ice cube is added*

t_j = *time at which ice cube starts to float*

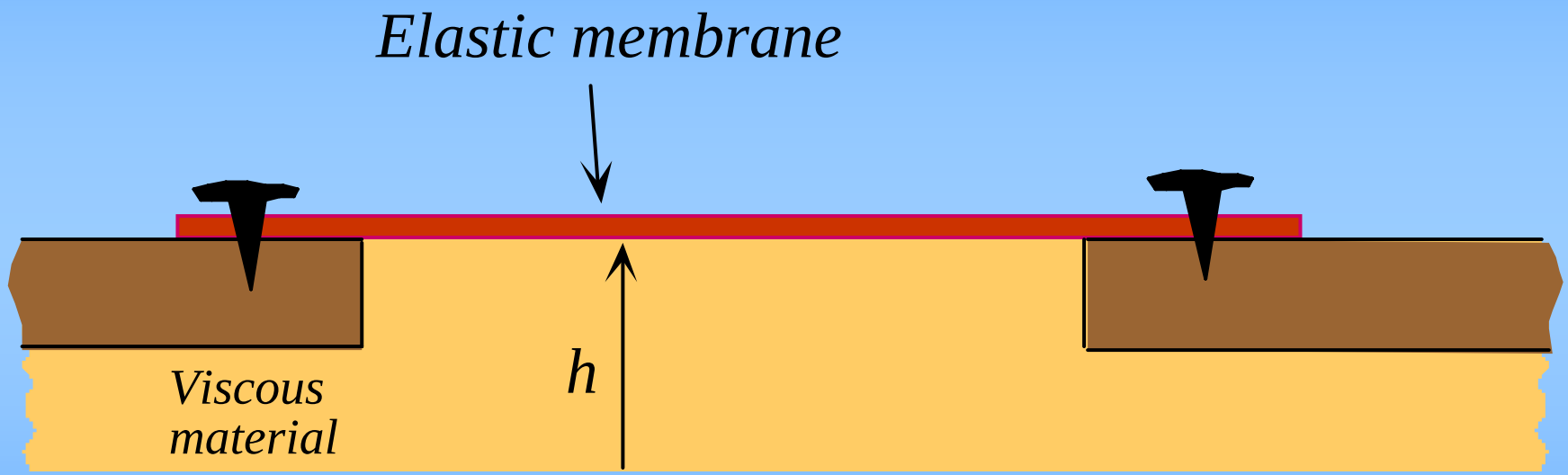


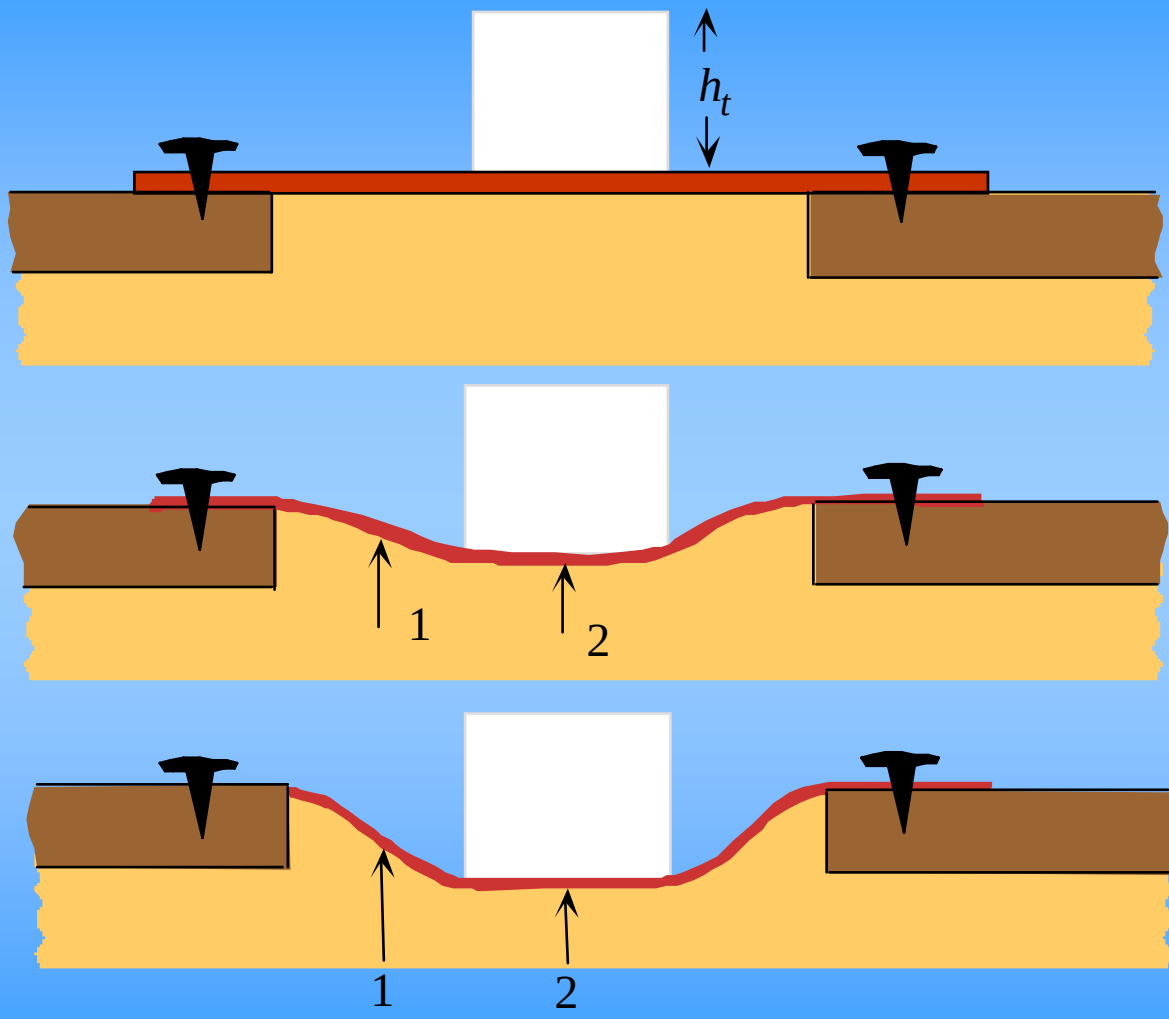


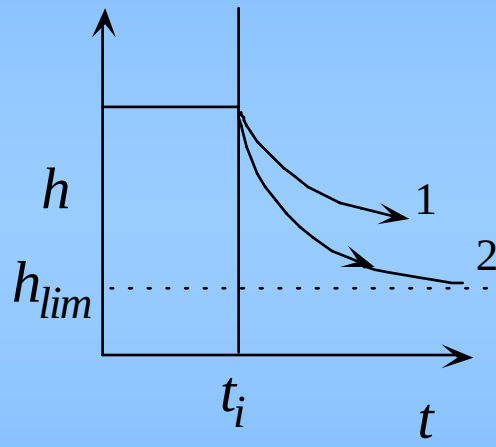
$$f_A = k \frac{dm}{r_A^2}$$

$$f_B = k \frac{dm}{r_B^2}$$

$$f_B > f_A$$

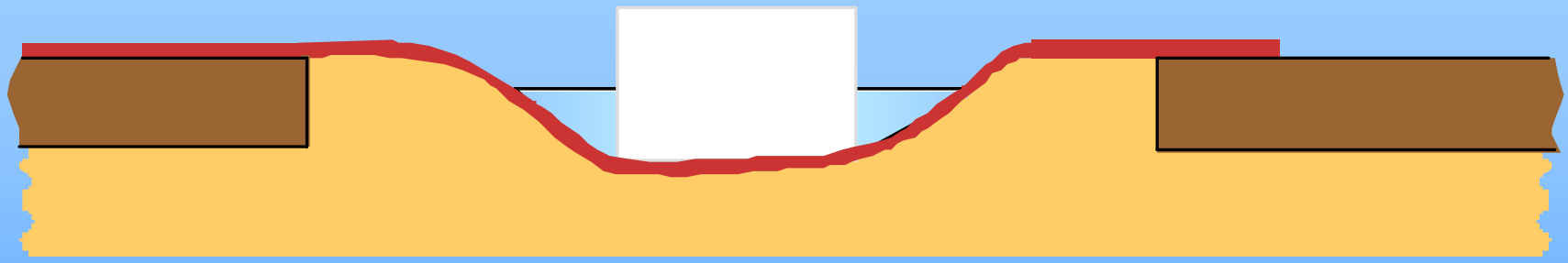

Elastic membrane
h
Viscous material





$$h - h_{lim} = \frac{\rho_i}{\rho_m} h_i$$

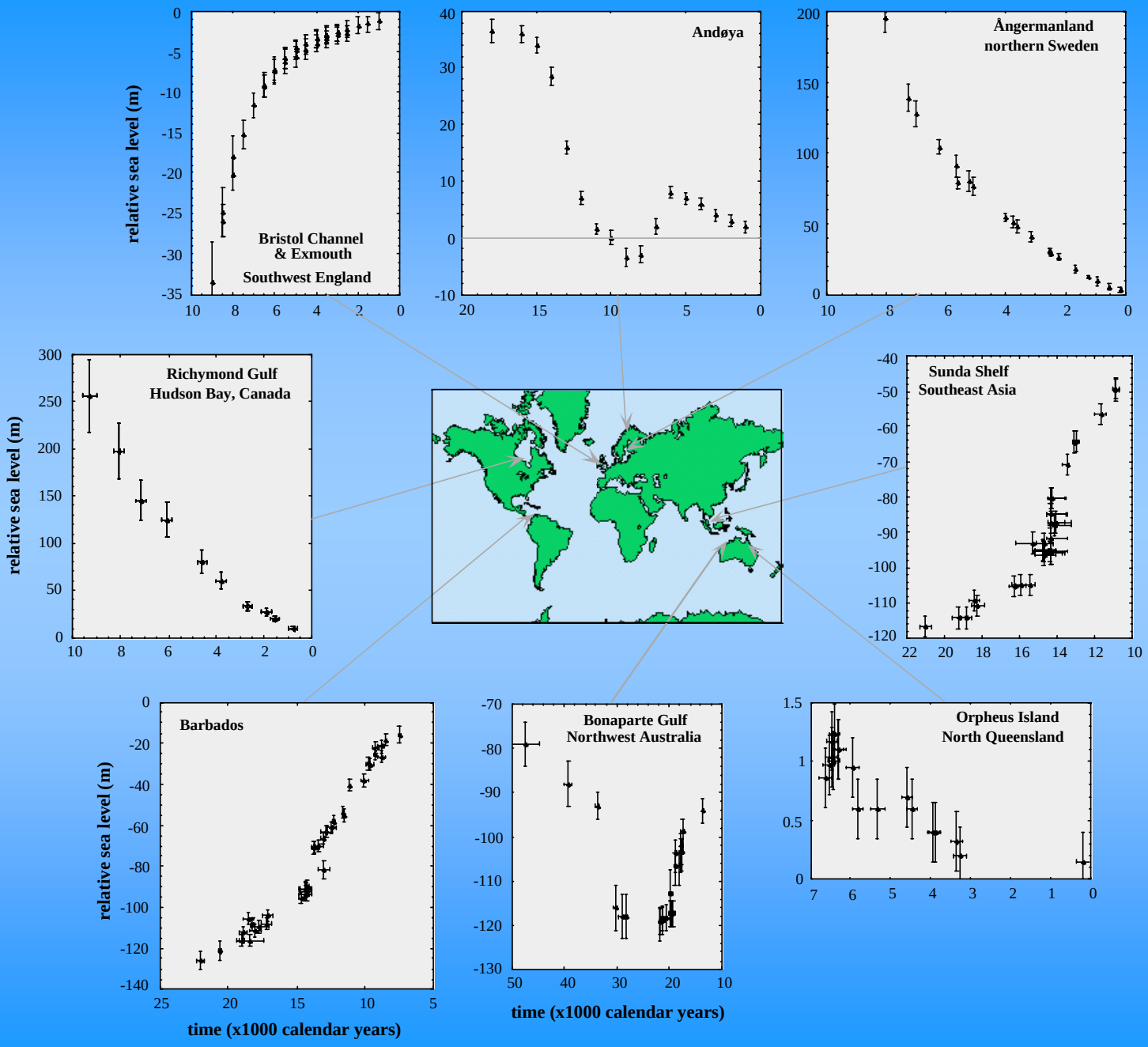
If ice melts, central load is decreased with time but meltwater also loads the membrane.

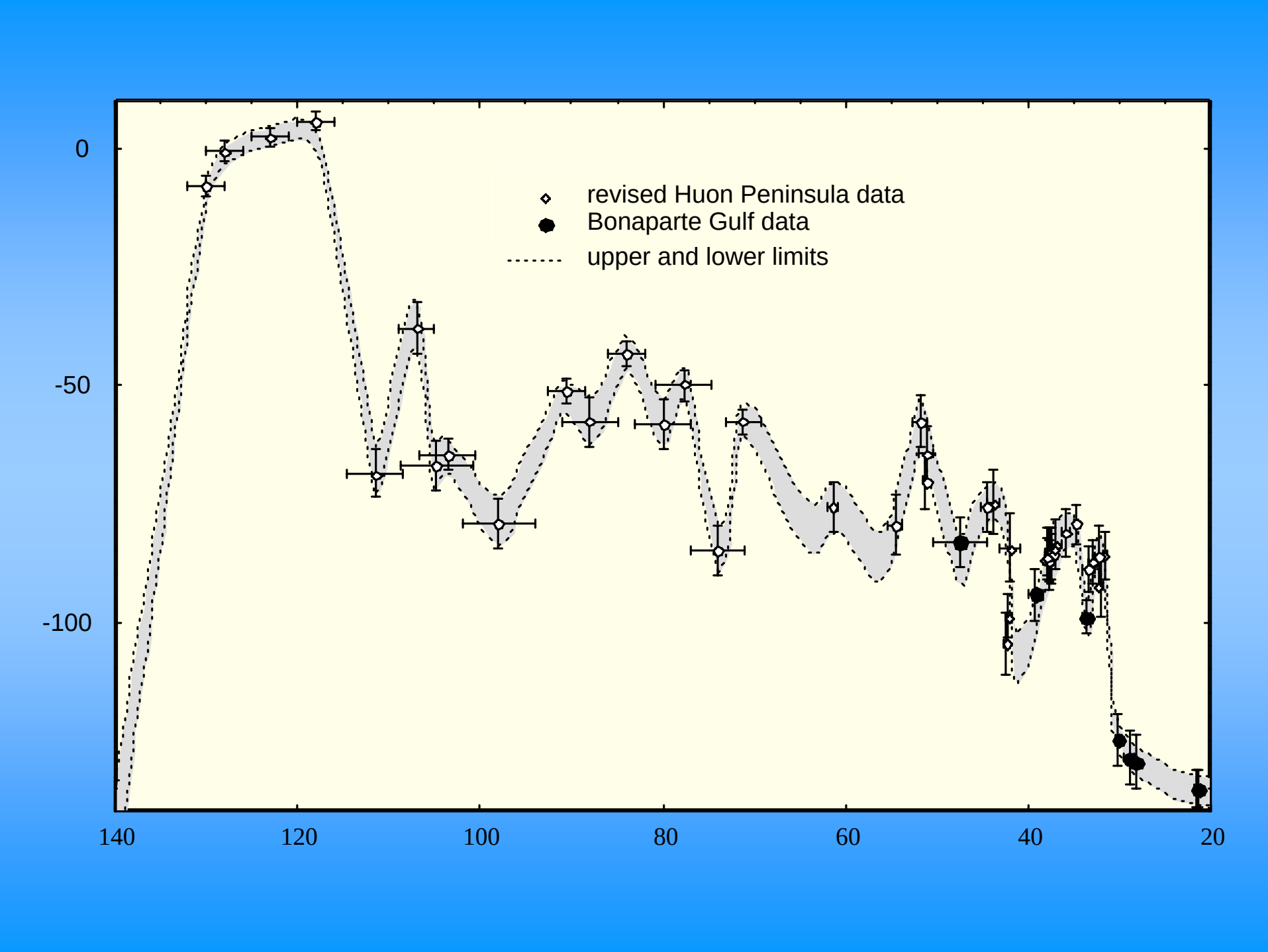


Tectonic disruption!

Summary: When ice sheets melt we can expect:

1. Change in position of sea surface that varies with time and with location.
2. Deformation of the earth under the changing ice and water load (earth material is viscous under certain conditions).
3. Observations of these changes link to size and locations of ice mass and to viscosity of earth.

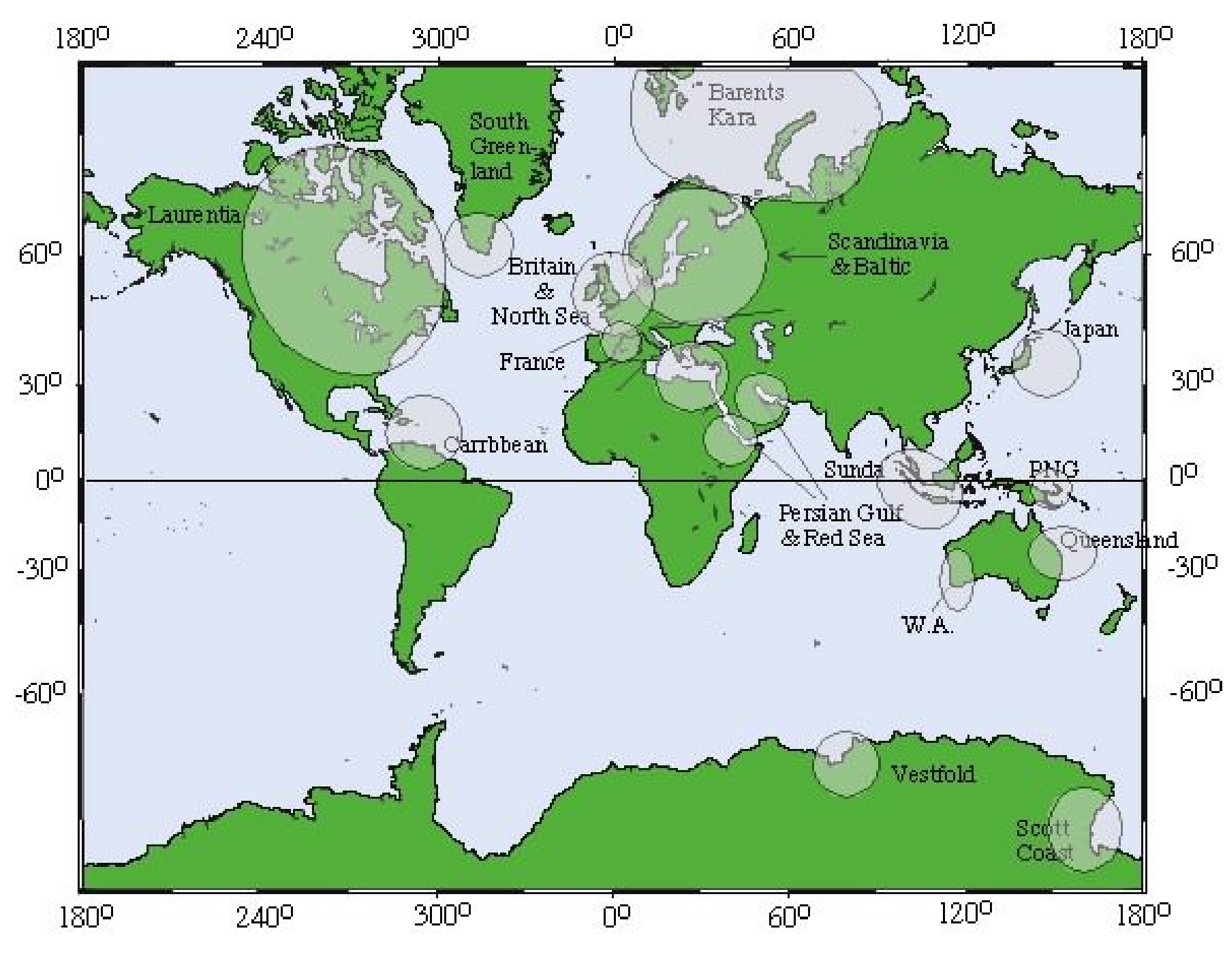

relative sea level (m)
Bristol Channel
& Exmouth
Southwest England
Andøya
Ångermanland
northern Sweden
Richymond Gulf
Hudson Bay, Canada
Sunda Shelf
Southeast Asia
Barbados
Bonaparte Gulf
Northwest Australia
Orpheus Island
North Queensland
time (x1000 calendar years)
time (x1000 calendar years)


0
-50
-100
140
120
100
80
60
40
20
revised Huon Peninsula data
Bonaparte Gulf data
upper and lower limits

Observations.

What we see in evidence that sea levels have been both higher and lower than present sea level.

- Ancient shorelines above present sea level
  (e.g. Sweden)
- Coral reefs above present sea level
  (e.g. Papua New Guinea, Barbados)
- Foundations of ancient temples now in water
  (e.g. Kenchria, Greece)
- Roman-period fish tanks below sea level
  (e.g. coast of Italy)
- Marine sediments in lakes that are
  now freshwater (e.g.Antarctic coast)


180°
240°
300°
0°
60°
120°
180°
60°
30°
0°
-30°
-60°
Barents
Kara
South
Green-
land
Laurentia
Scandinavia
& Baltic
Britain
&
North Sea
France
Japan
Carribbean
Sunda
PNG
Persian Gulf
& Red Sea
Queensland
W.A.
Vestfold
Scott
Coast