" Are you kidding? Do you know how hard it is to clean one of them?!?!"

Teaching Earth Science with Controversy: The Role of the History and Philosophy of Science

GSA Short Course Teaching with Controversy
31 October 2015

Glenn Dolphin, PhD
Tamaratt Teaching Professor – Department of Geoscience

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Goals for this presentation

- Build a case for use of scientific controversy and HPS in teaching science
- Demonstrate an approach for utilizing history and inquiry to teach
  - science content
  - nature of science
- Give some resources for utilizing HPS in science class

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But first, a story…

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Menu

- Broiled Accountant $5.95 per plate
- Fried Engineer $7.95 per plate
- Toasted Teacher $7.95 per plate
- Grilled Geologist $25.95 per plate

http://www.classicistranieri.com/punch/1/3/5/6/13563/13563-h/images/009.png

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Unit 4 - The Atmos-phere and the Oceans

Unit 5 - Dynamic Earth

- Plate Tectonics
  - -Drifting Continents
  - -Seafloor Spreading
  - -Theory of Plate Tectonics
  - -Causes of Plate Motion
- Volcanic Activity
  - -Magma
  - -Intrusive Activity
  - -Volcanoes
- Earthquakes
  - -Forces Within Earth
  - -Seismic Waves and Earth's Interior
  - -Measuring and Locating eq's
  - -Earthquakes and society
- Mountain Building
  - -Crust-Mantle Relationships
  - -Convergent Boundary Mountains
  - -Other Types of Mountains

Unit 6 – Geologic Time

Rifting

Converging

Mohorovicic Discontinuity

Earthquakes

Magnetic anomalies

Seafloor spreading

Subduction

Orogeny

Decompression melting

Porphyroblastic

Mantel convection

Pyroclastic

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There is a strong temptation to assume that presenting subject matter in its perfected form provides a royal road to learning. What more natural than to suppose that the immature can be saved time and energy, and be protected from needless error by commencing where competent inquirers have left off?...

The outcome is written large in the history of education. Pupils begin their study . . . with texts in which the subject is organized into topics according to the order of the specialist. Technical concepts and their definitions are introduced at the outset. Laws are introduced at an early stage, with at best a few indications of the way in which they were arrived at. . .

The pupil learns symbols without the key to their meaning. He acquires a technical body of information without ability to trace its connections [to what] is familiar—often he acquires simply a vocabulary (Dewey, 1916, p. 220).

How do we “do” geology?

Earth: Portrait of a planet 4th ed.
Marshak, 2013
1. Recognize the problem
2. Collect data
3. Propose hypothesis
4. Test hypothesis

Exploring Geology
Reynolds, et al 2013
1. Make observations
2. State the problem (succinctly)
3. Ask a question
4. Create hypotheses
5. Make predictions
6. Test predictions

How do we “do” geology?

Environmental geology 9th ed
Keller, 2011

1. Ask a question or make observations
2. Create a hypothesis to answer question
3. Test hypothesis: Data collection, organization and analysis
4. Interpret data and draw conclusions
5. Reject or accept hypothesis
6. More tests of supported hypothesis leads to theory

Physical Geology 4th ed.
Plummer et al, 2013

1. A question of problem is raised
2. Gathering data
3. Hypothesis is proposed (and is constantly subject to being proven false)
4. Prediction
5. Predictions are tested
6. Hypothesis becomes theory

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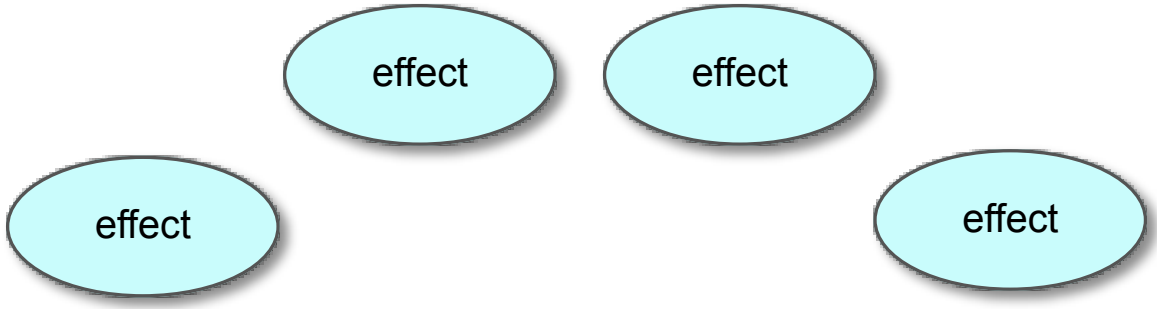
Historical Science



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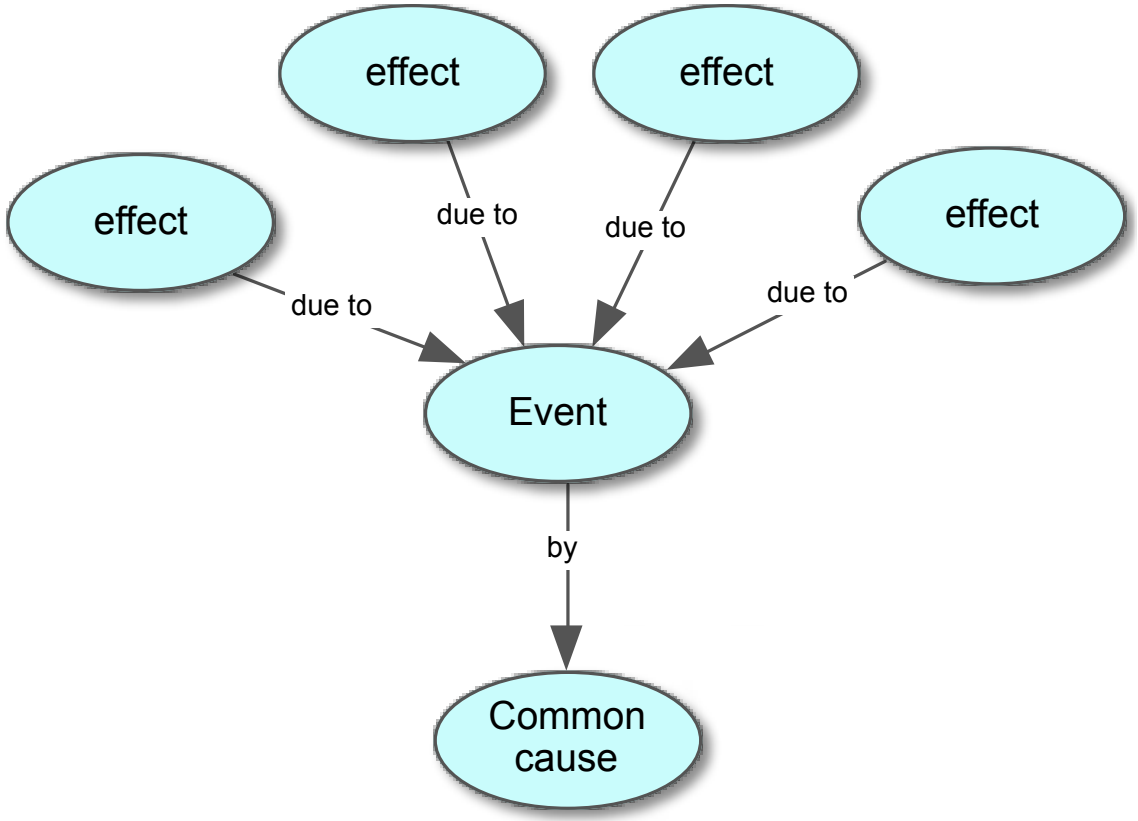
Historical Science



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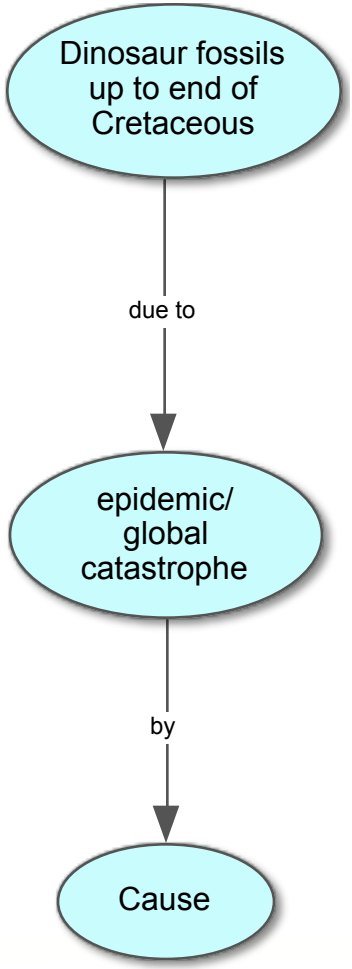
Historical Science



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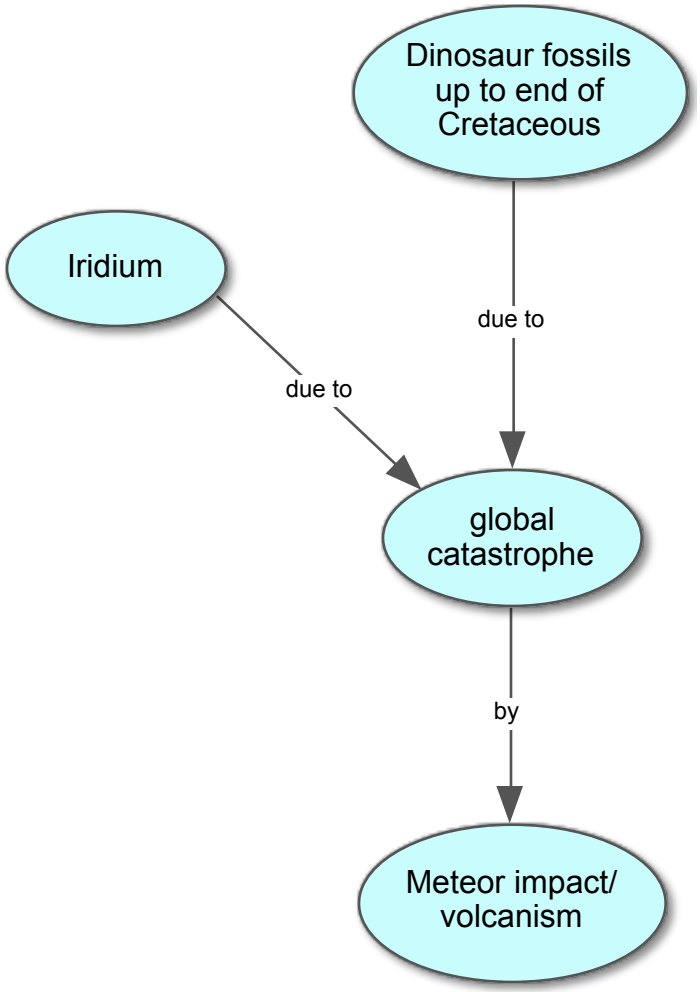
Historical Science



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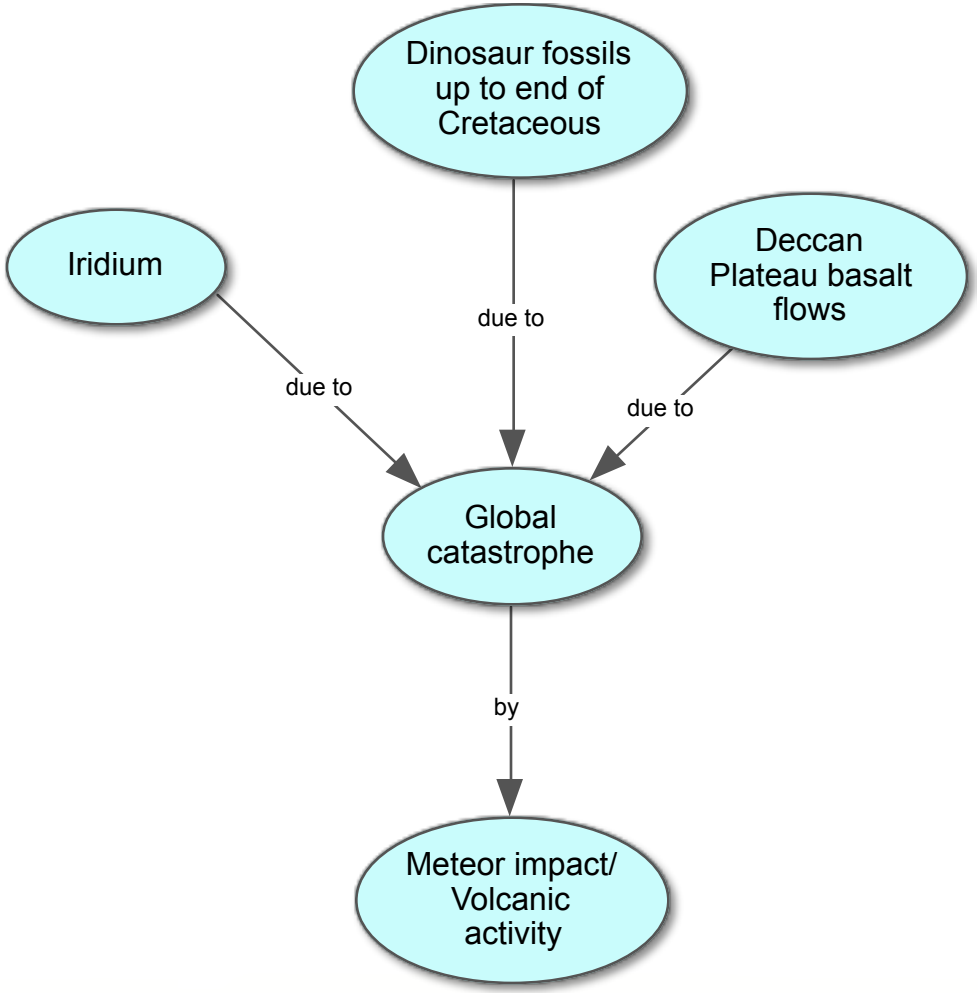
Historical Science



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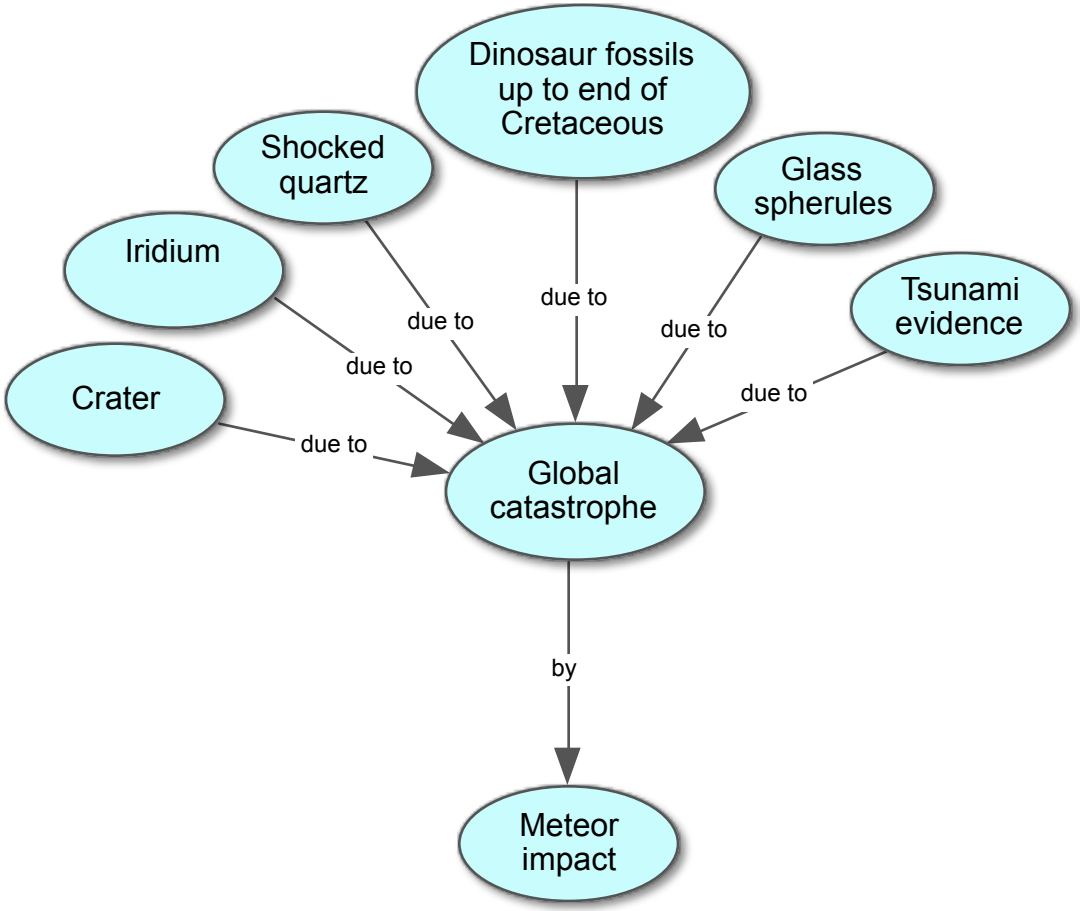
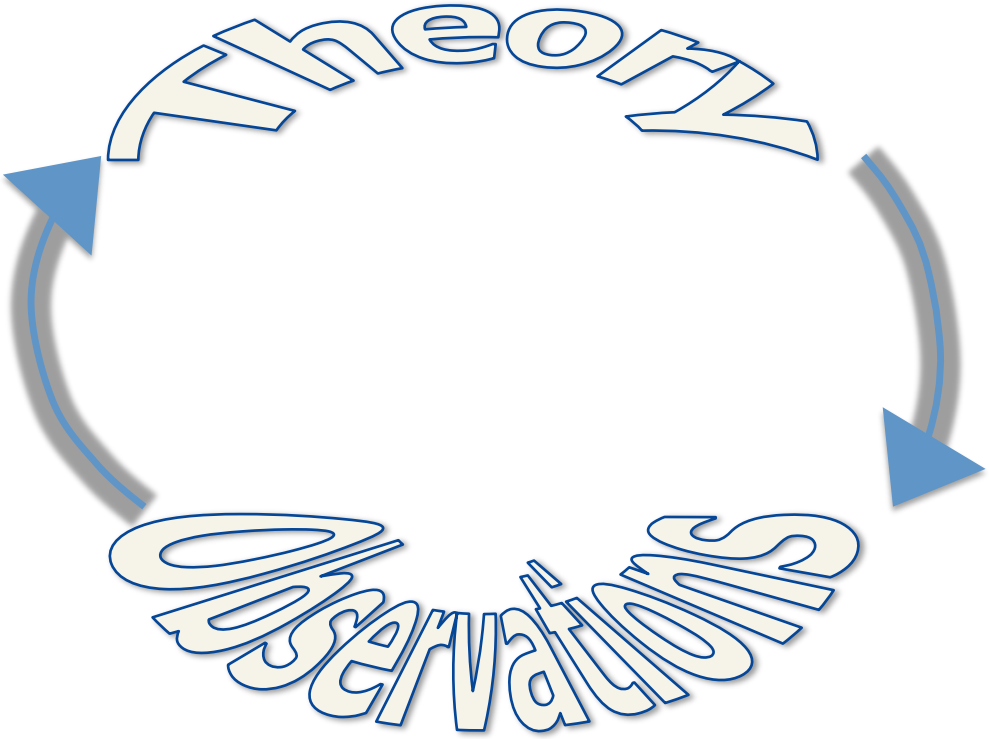
Historical Science



Hermeneutic (Frodeman, 1995)



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Why use controversies? (Dodick & Dolphin, 2013)

- Cognitive dualists (Alters & Nelson, 2004)
- Old concepts can play a role in learning new ones… (Carey, 2009; Clement, 2009; diSessa, 1998; Nersessian, 2008)
- Learning through comparison (Marton et al, 2004)
- Learning through argument (Veerman, 2003)
- Multiple Working Hypotheses (Chamberlin, 1890; Gilbert, 1886)

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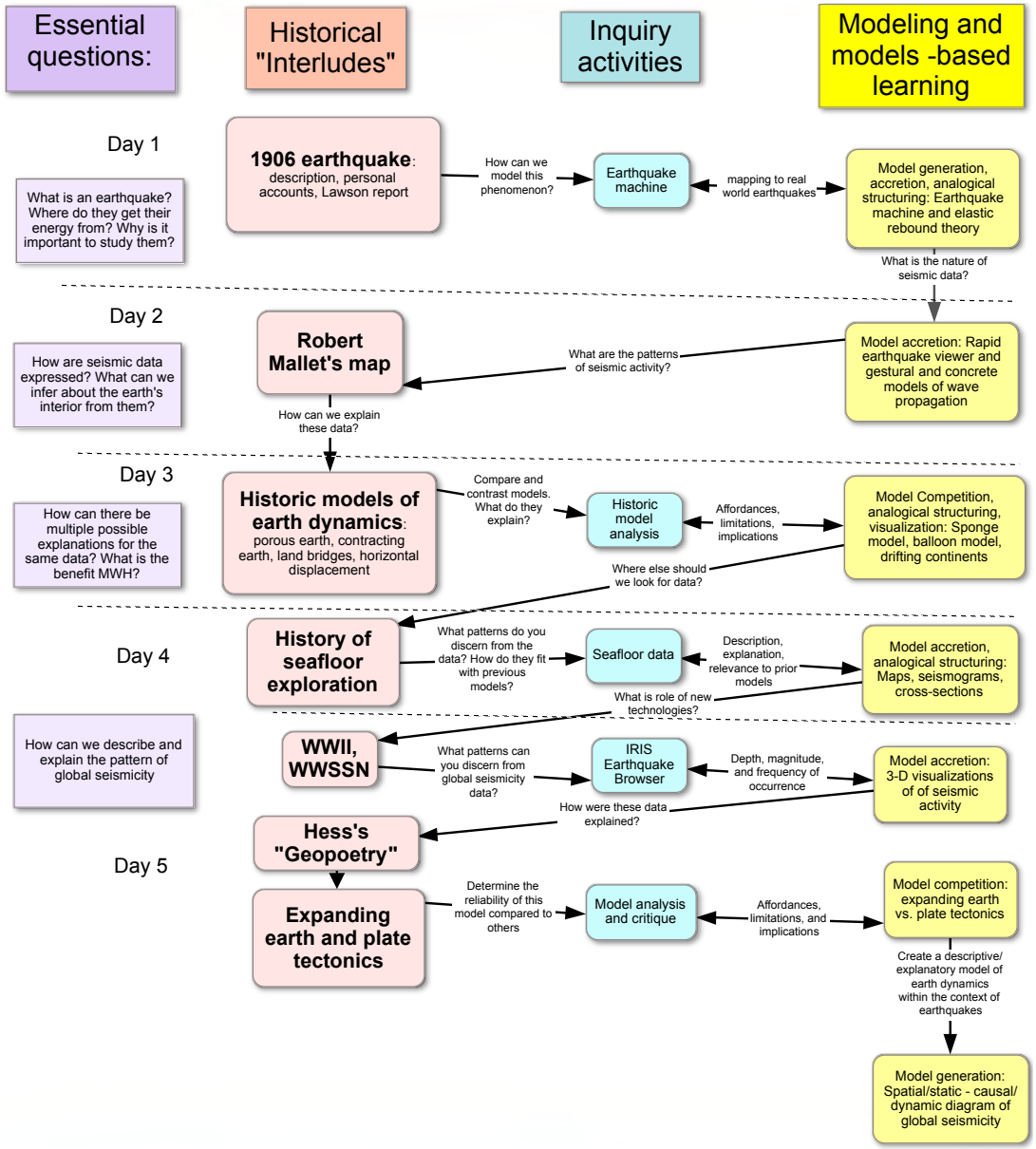
Braiding history, inquiry, model-building



EXTRA! EXTRA! EXTRA!

THE EVENING TELEGRAM

GREAT EARTHQUAKE KILLS 1000 PEOPLE IN SAN FRANCISCO

NEW YORK, April 18.—A fearful earthquake killed 1000 peopl in San Francisco between 5 and 6 this morning.

CATASTROPHE IS COLOSSAL

RAILWAY BUILDERS ARE HANDICAPPED

Scarcity of Labor Seriously Delays Construction Work.

BUTTE BANKERS MAY LOCATE IN THE ROSE CITY

ROOPERS PREPARE FOR LONG MARCH

THE EVENING TELEGRAM HAS THE ONLY WI

THE EVENI

VOL. LIX. THIRD EDITION PORTLAND, ORE

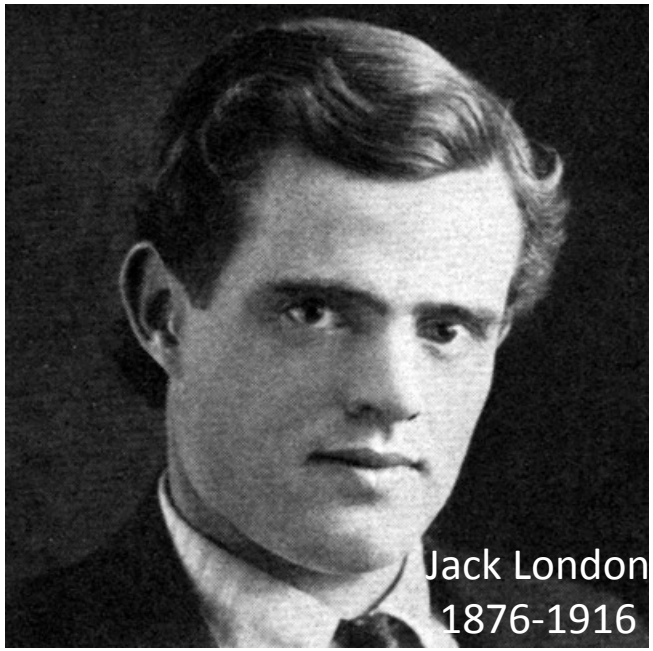
300,000 PEOPLE ARE HOMELESS

Queen City Abandoned, Prey to Flames That Follow Quake.

Citizens Flee For Their Lives and Watch Homes Burn.

PORTLAND WILL SEND FOOD AND MONEY FOR DISTRESSED

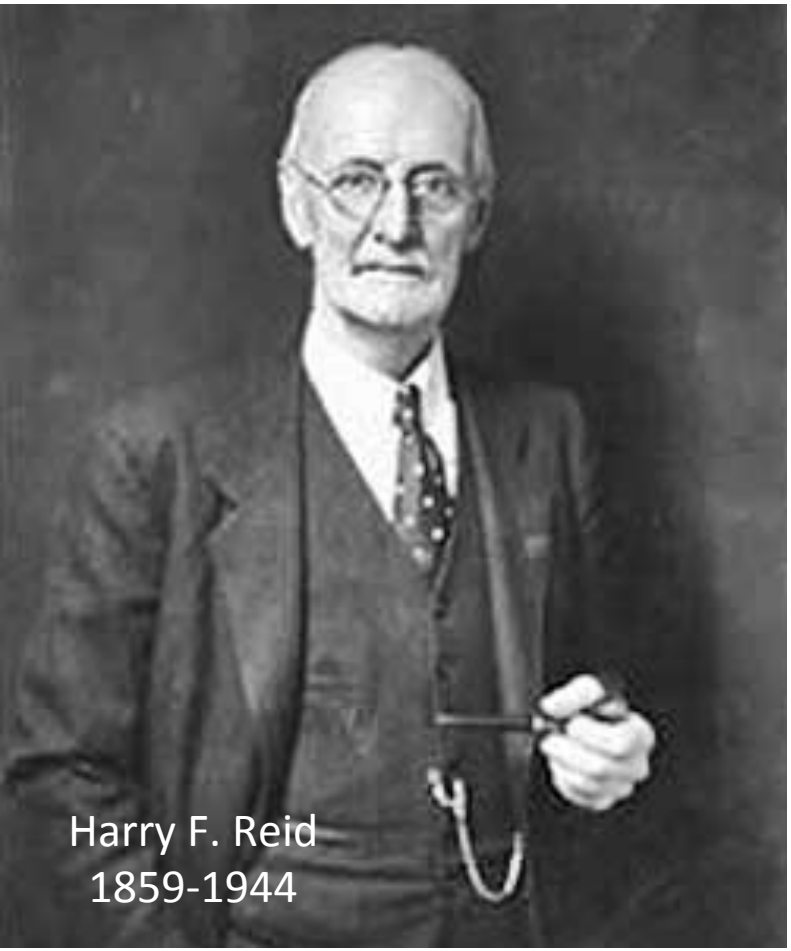
At a meeting of Representatives of Commercial Bodies, Officials and Citizens' held at noon, steps were taken for the immediate preparation of a special train of nine carloads of supplies to be dispatched to San Francisco tonight. Donations are asked for.


Jack London
1876-1916

•Illegitimate child growing up in poverty in San Francisco and Oakland
•At 17 went to sea on a sealing ship
•Ran for mayor of Oakland under the socialist party
•Became one of America's most prolific and successful writers, most notably fictional stories of men or animals overcoming environmental hardships


William James
1842-1910

•Born in NYC and lived there, in Europe, and Rhode Island
•Educated in private schools
•Suffered some physical and psychological ailments growing up
•Wrote mainly of philosophy and psychology


Harry F. Reid
1859-1944

- Born in Baltimore, MD.
- Was educated in the States and in Switzerland
- Studied math and physics (PhD)
- Studied behavior of glaciers – interest from living in Switzerland
- Became a Professor of geophysics at Johns Hopkins University
- Advanced seismology
- Proposed elastic rebound theory
- One of the first government commissioned scientific studies

How might Reid's work with glaciers have influenced his development of elastic rebound theory?

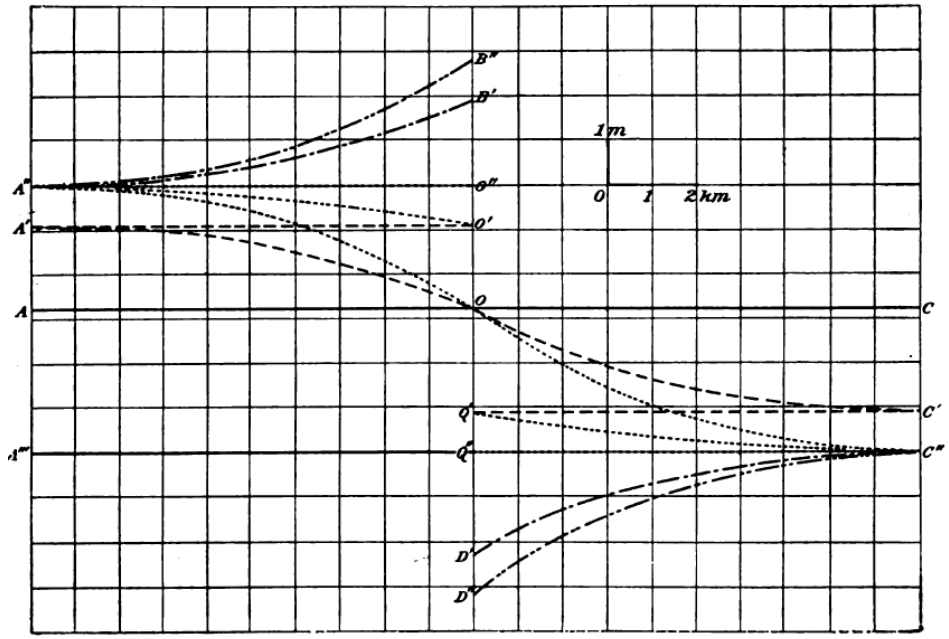
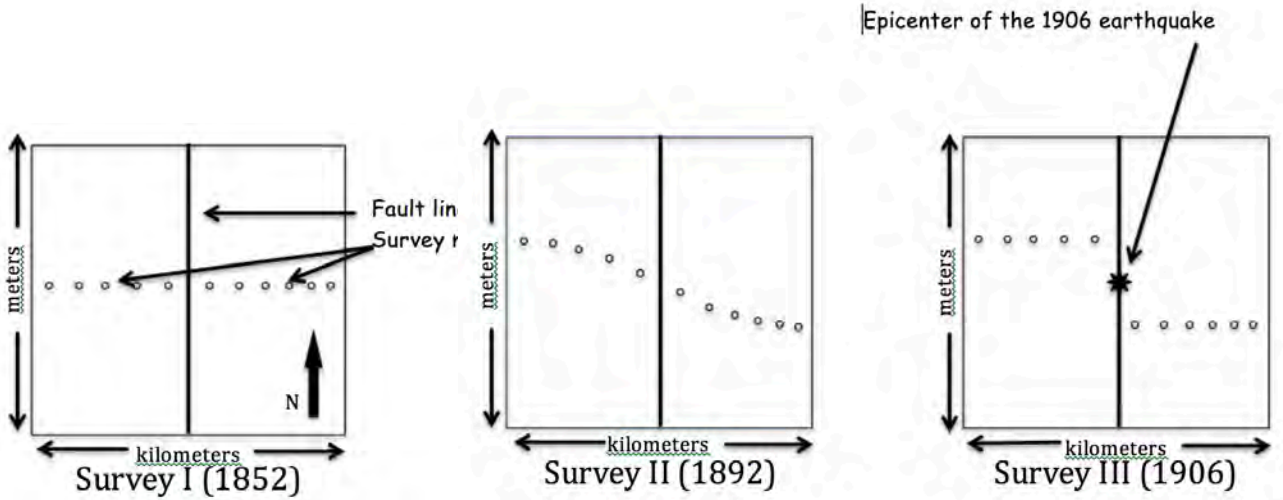

B''
B'
1m
0 1 2km
A''
O''
A'
O'
A
O
C
C'
C''
D'
D''

Fig. 6.


Epicenter of the 1906 earthquake
Fault lin
Survey
meters
N
kilometers
Survey I (1852)
meters
kilometers
Survey II (1892)
meters
kilometers
Survey III (1906)

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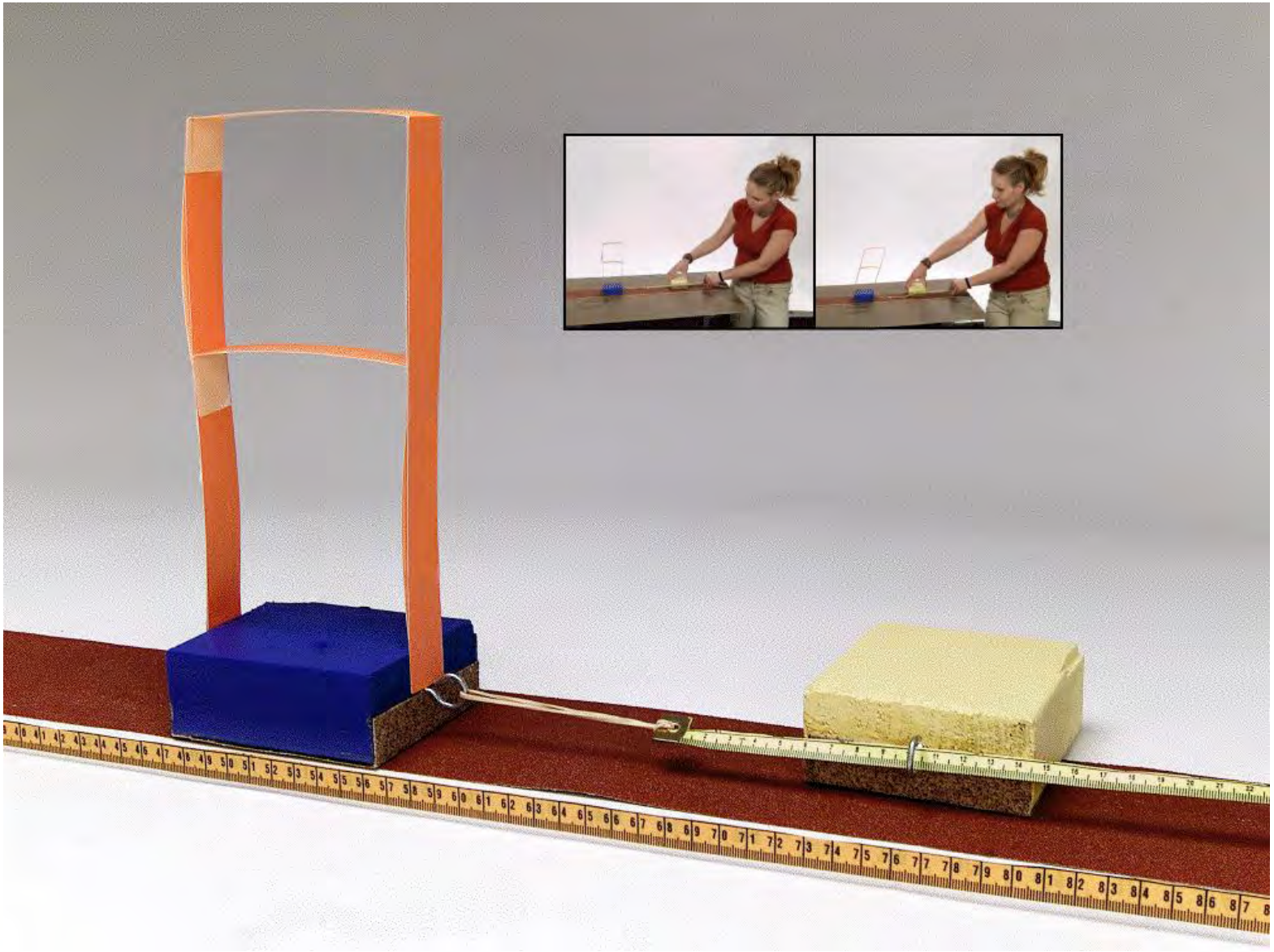
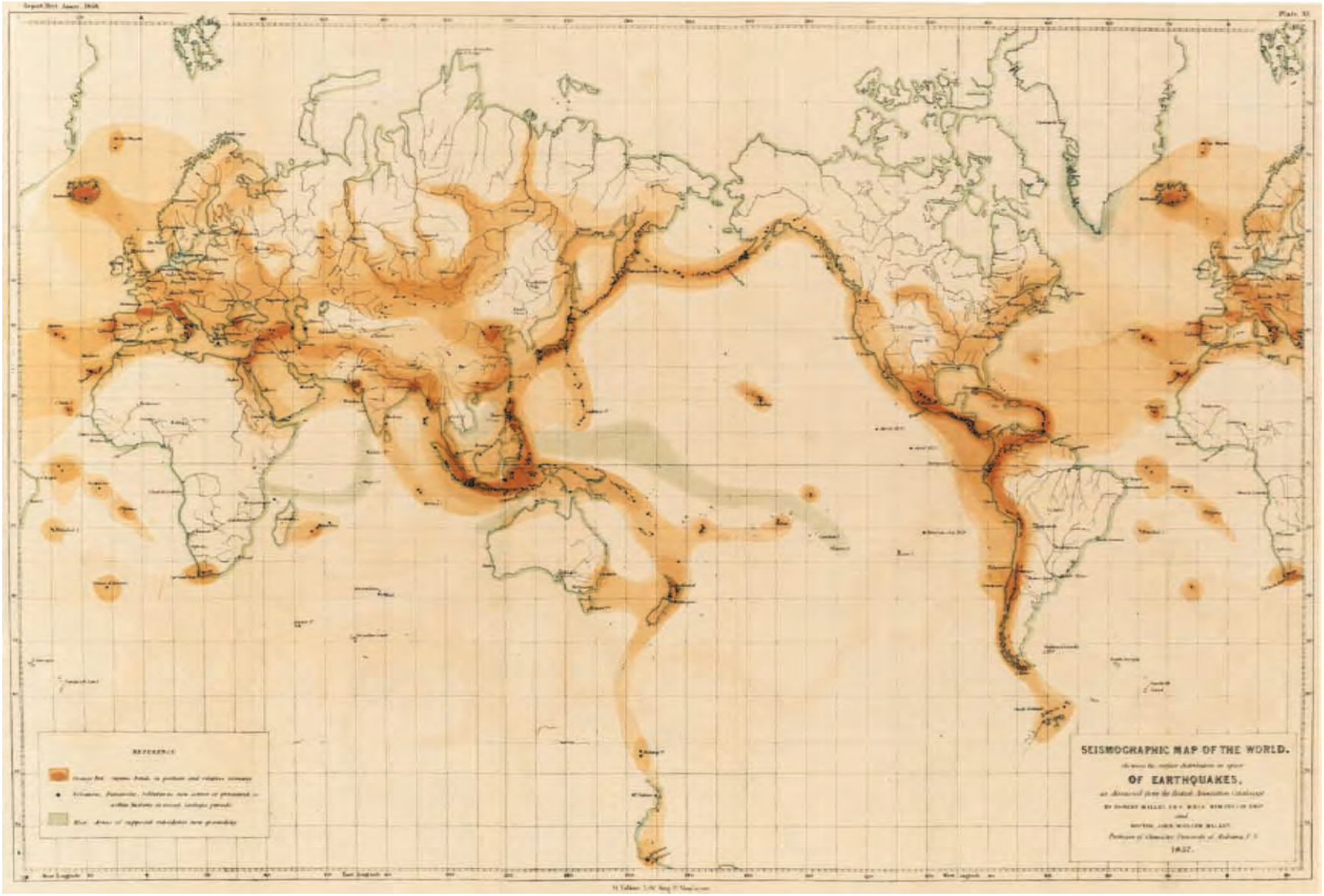



SEISMOGRAPHIC MAP OF THE WORLD.
OF EARTHQUAKES,
1857.

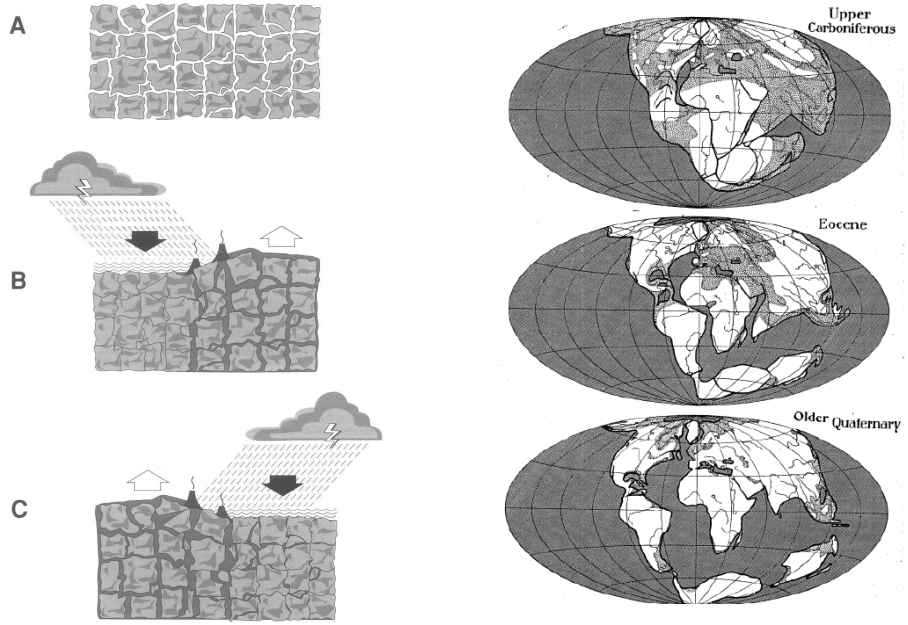


Fig. 1.

Fig. 2.

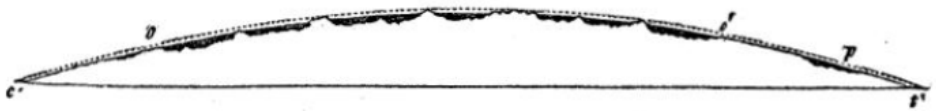
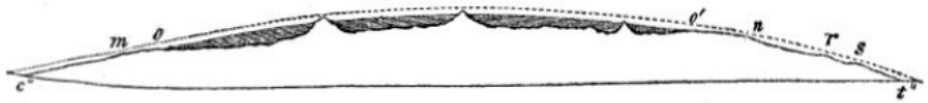
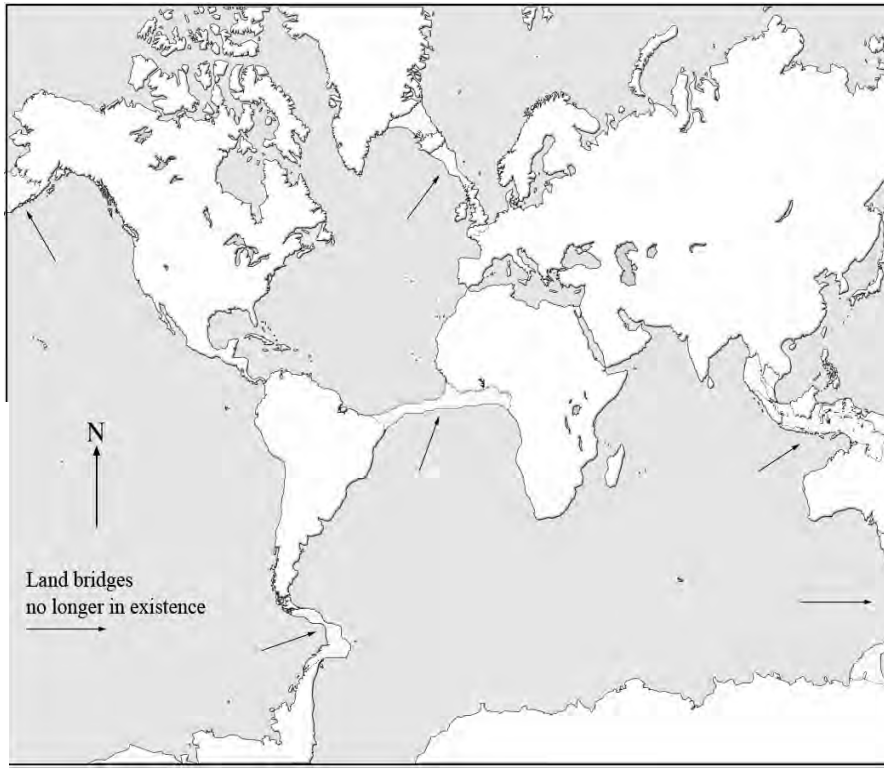


Fig. 3.





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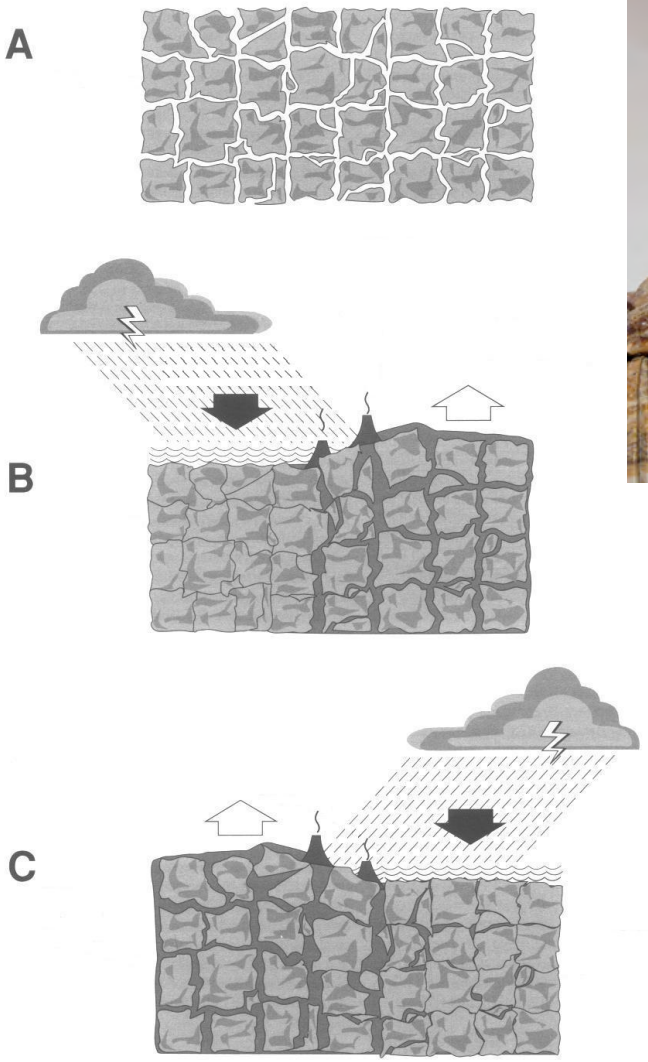
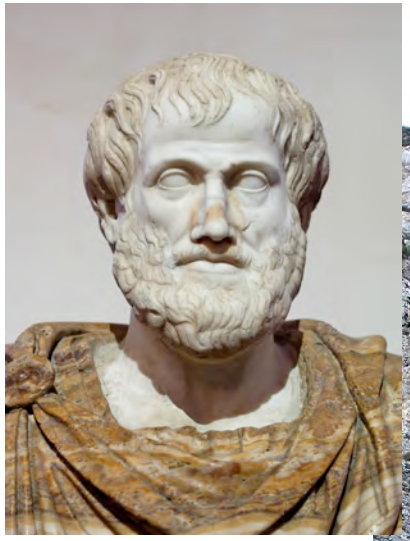
What are the implications of each proposal?

1. What do the models explain?
2. What predictions can you make from the models?
3. How could you test these predictions?





From Sengör, 2003. Used by permission.

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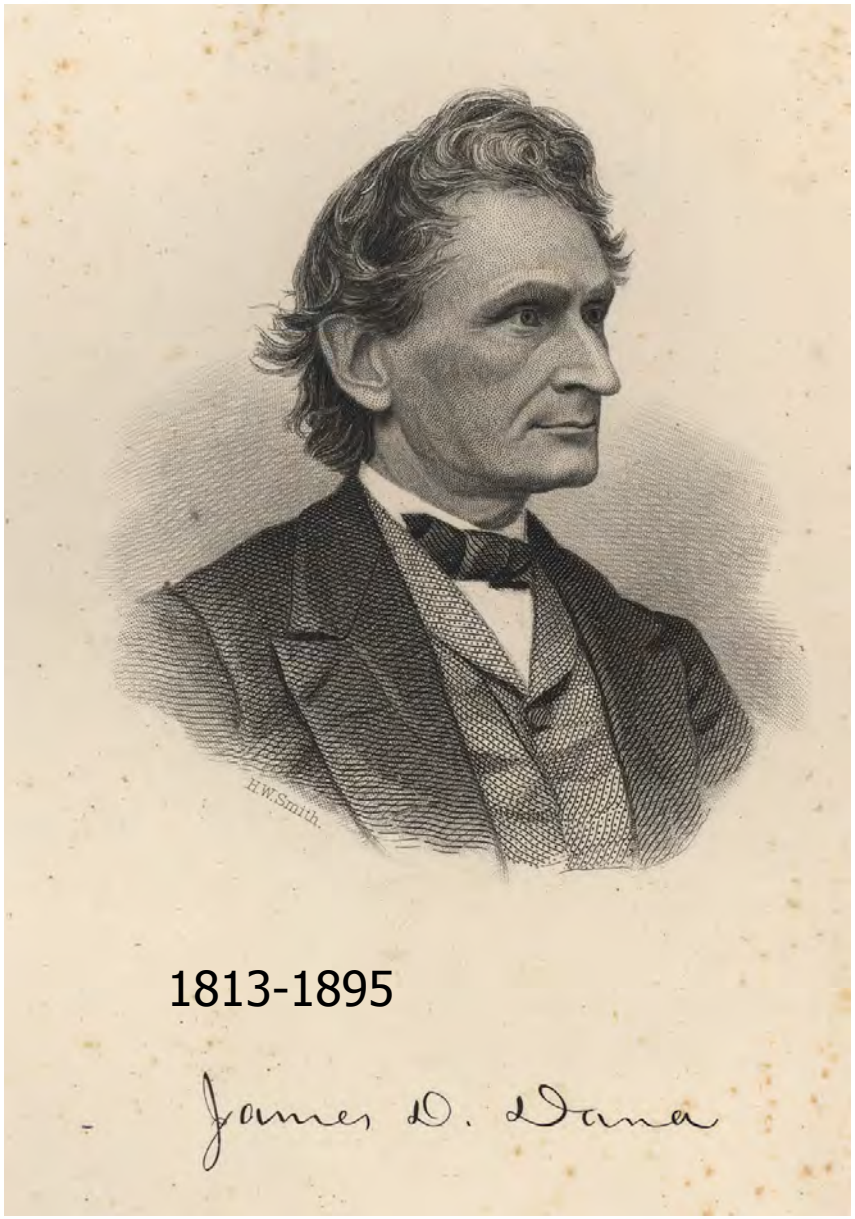
But, is a sponge a reasonable model for the earth?



1813-1895

1831-1914

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Fig. 1.

Fig. 2.

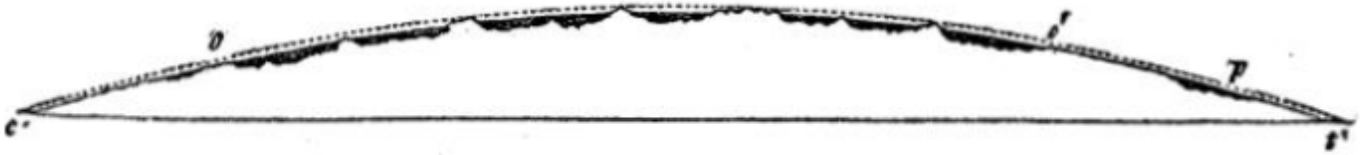
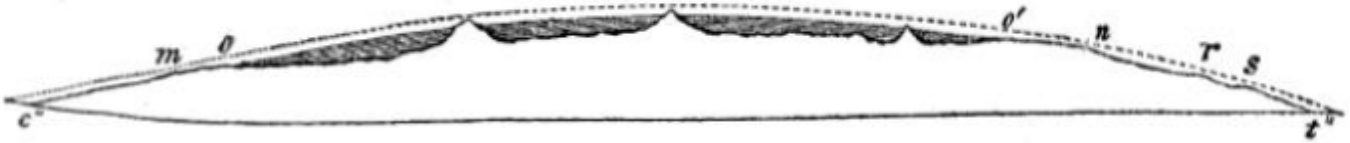


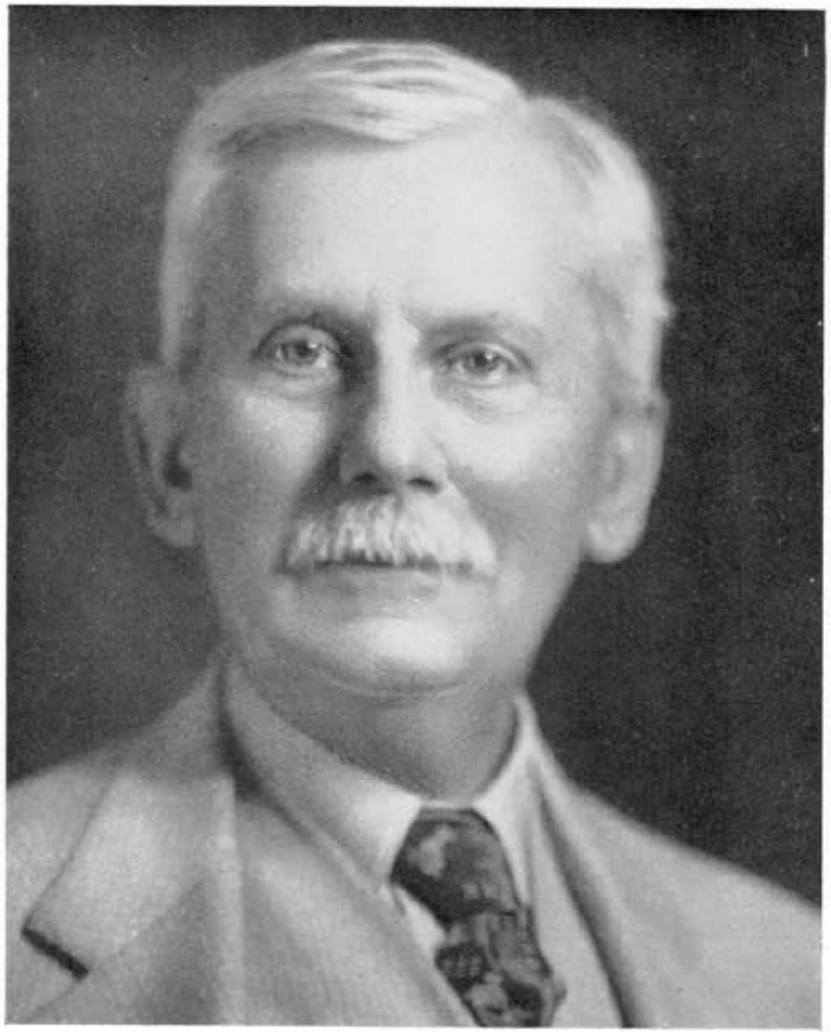
Fig. 3.



What about plate tectonics and mountains?

the pattern of mountains?

observations?

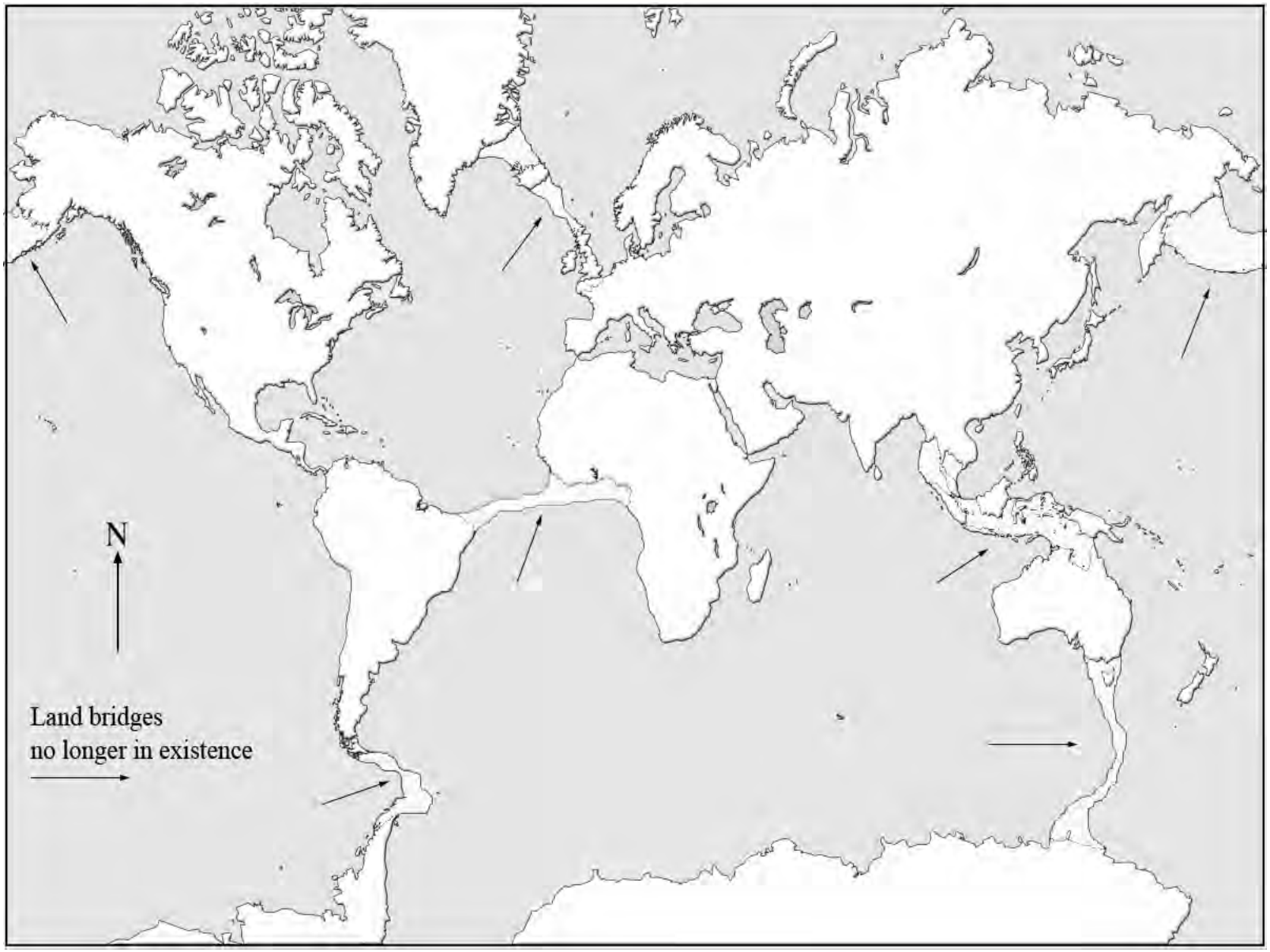


Charles Schuchert

1858-1942

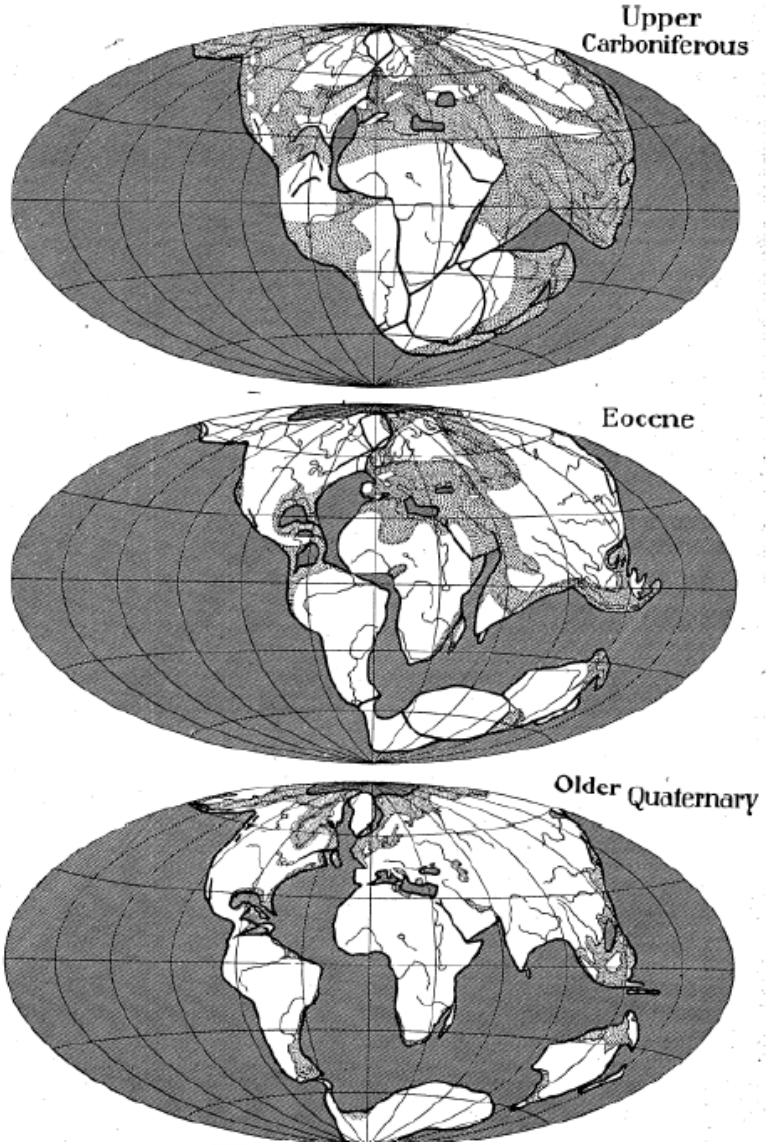
Bailey Willis
1857-1949

Bridging the gap


N
Land bridges
no longer in existence

1880-1930

Alfred Wegener.



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Was it because Wegener had no mechanism?

- Ice ages and magnetism accepted with no mechanism
- Europe, S. Africa, Australia "OK" with Drift
- Mantle convection by Joly (1920) and Holmes (1929)
- Concerns about a priori data collection, not MWH
- Did not fit with the (Lyell's) narrow idea of "uniformity"
- "If we are to believe Wegener's hypothesis we must forget everything which has been learned in the last 70 years and start all over again." (R. Chamberlin, 1928)

In all cases

- Models were based on observations of the natural world
- Context and/or personal experiences/bias played a role in knowledge construction
- “pieces” of “truth” in each
- Which has the most explanatory power?

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The ocean as a vast unknown territory

…like hovering in a balloon high above an unknown land which is hidden by clouds…

It has often been said that studying the depths of the sea is like hovering in a balloon high above an unknown land which is hidden by clouds, for it is a peculiarity of oceanic research that direct observations of the abyss are impracticable. Instead of the complete picture which vision gives, we have to rely upon a patiently put together mosaic representation of the discoveries made from time to time by sinking instruments and appliances into the deep.

Murray & Hjort, 1912 “The Depths of the Oceans”

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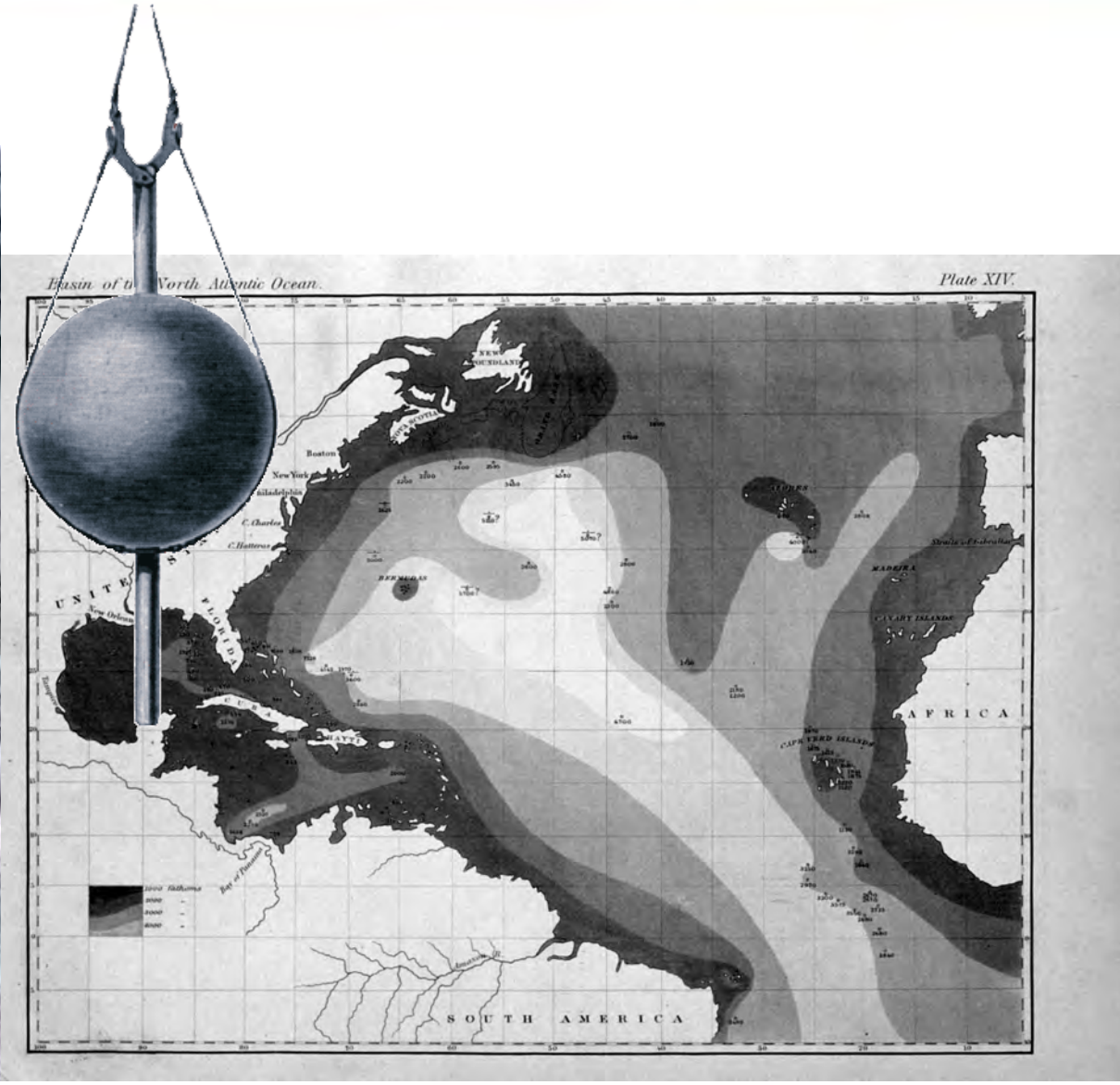
The Unknown Land (early 1800s)



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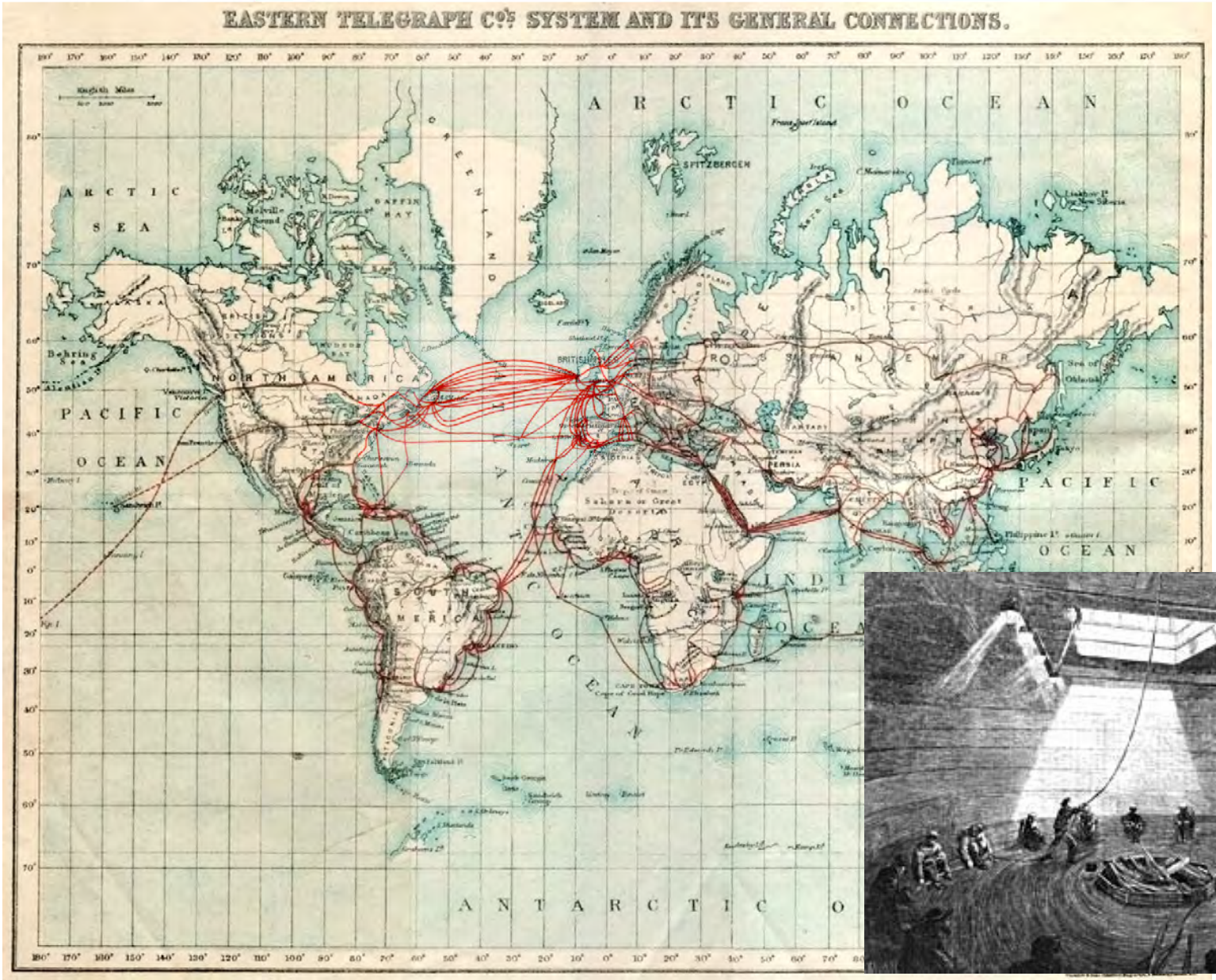

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But, it wasn't just because we wanted to make more phone calls…

WWII and German U-boats, International Geophysical Year (1957-58), Nuclear proliferation and the World Wide Synchronized Sesimic Network

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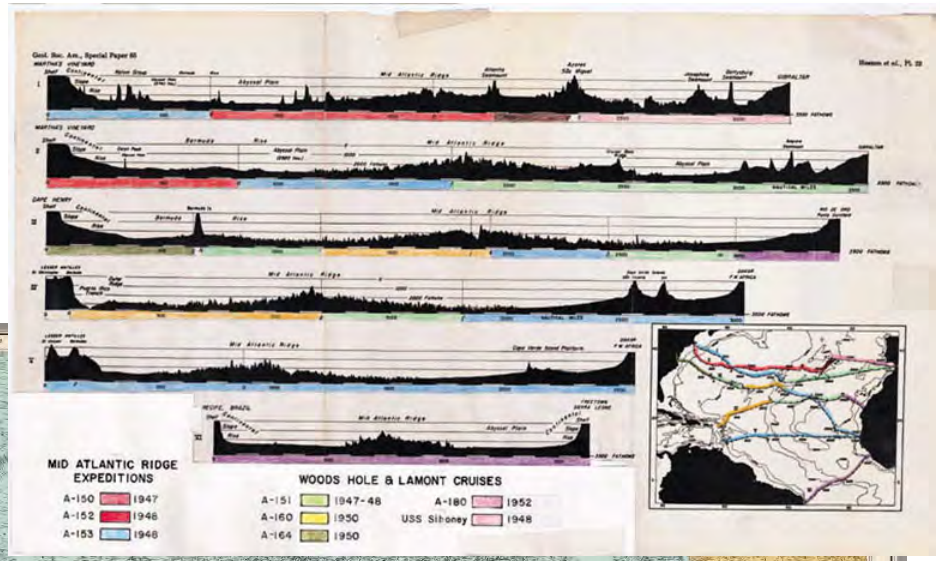

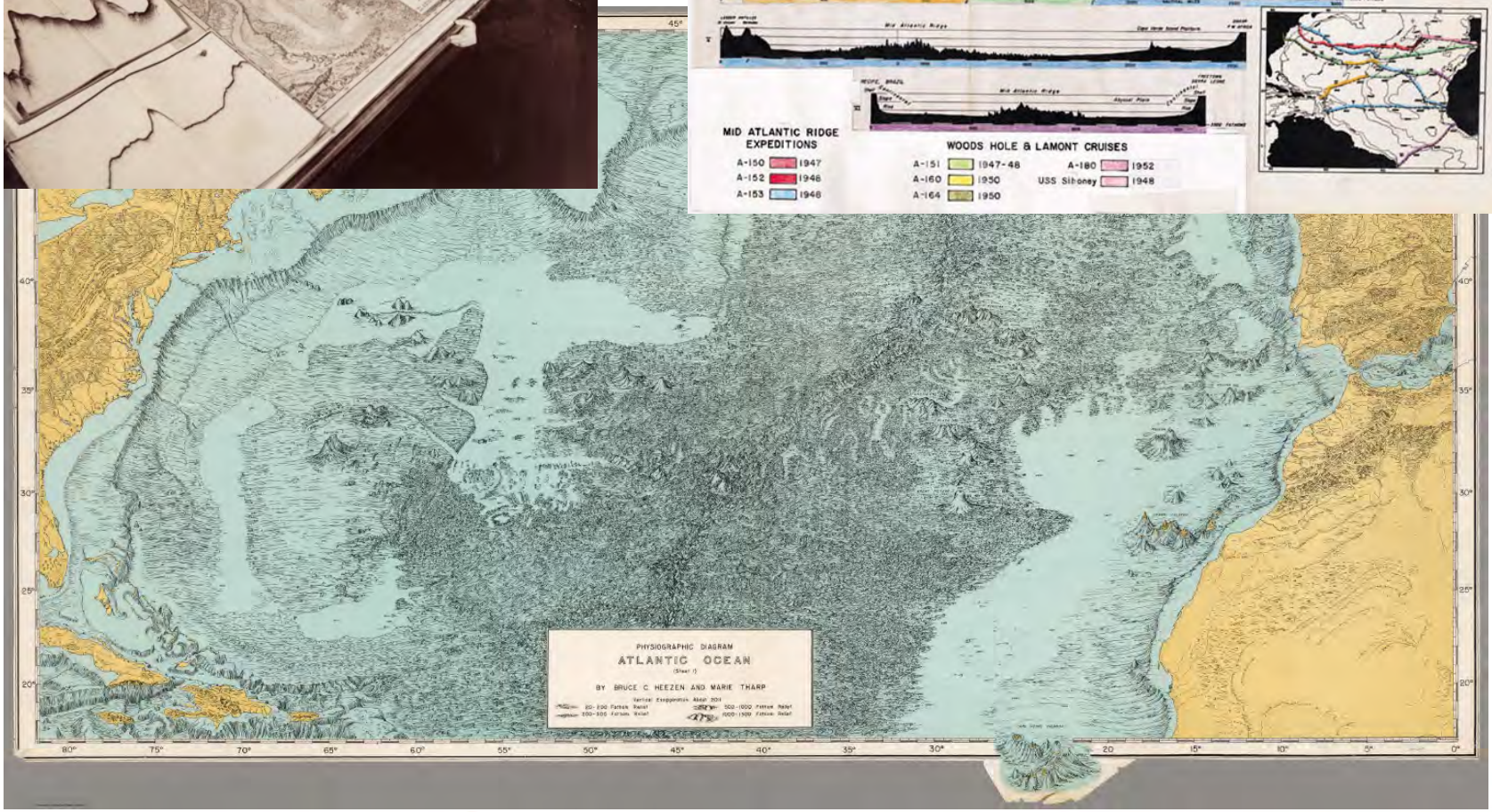

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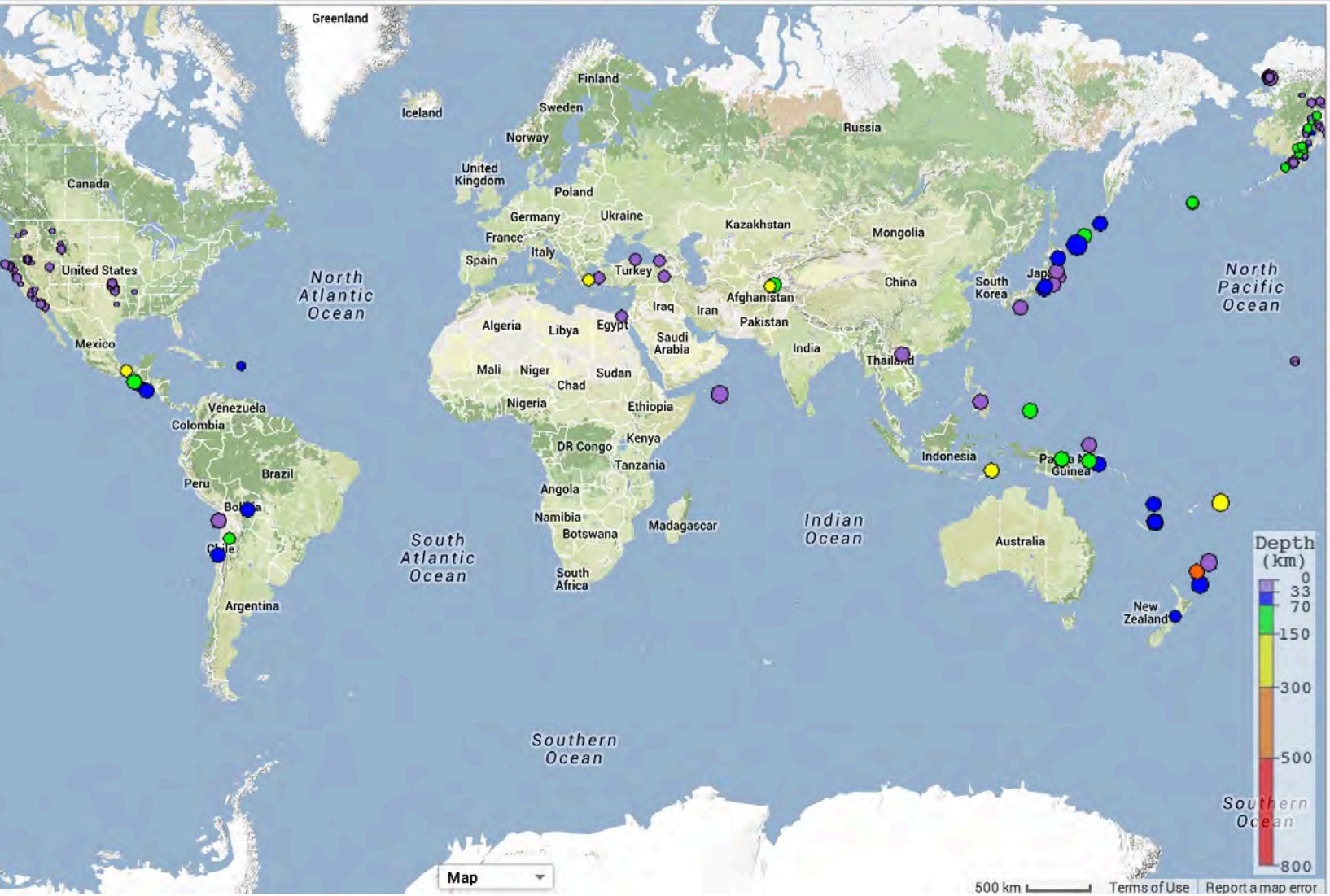
IRIS Earthquake Browser



Options

Make changes, press Apply:

Max quakes: 200

Priority: Newer

Time Range:

Magnitude Range:

Depth Range (km):

Apply

Earthquake Count:
200 of 3406694 (200 visible

Other things to try:

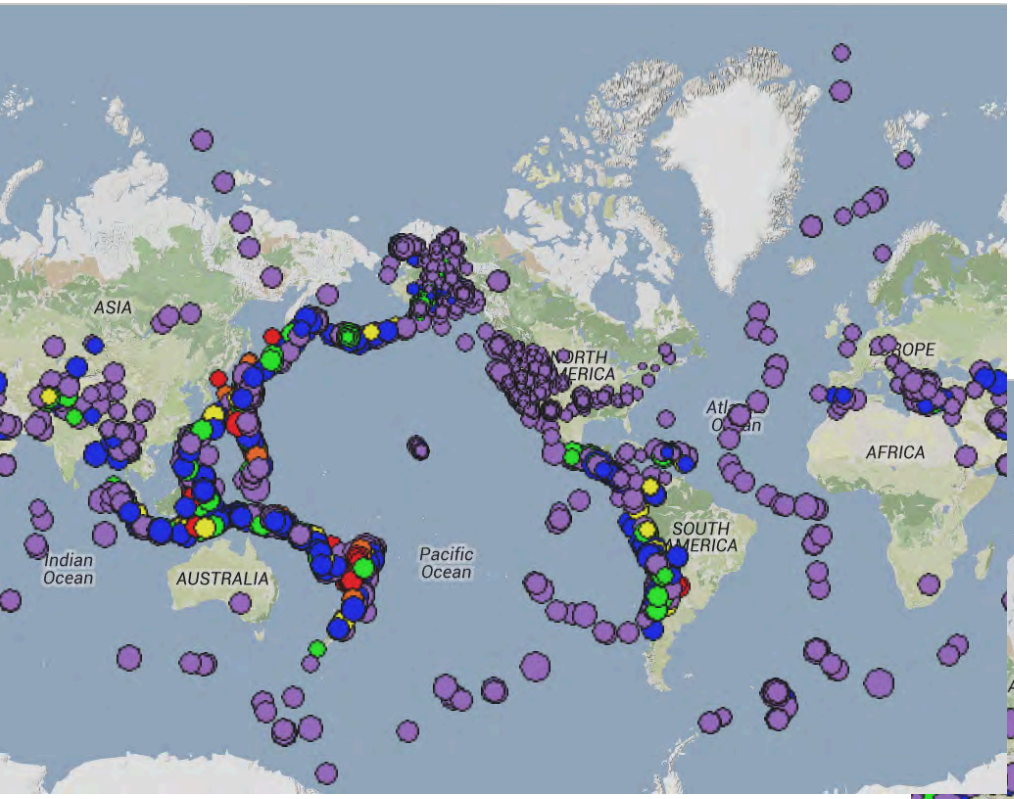
Show plates: Off

Go to: Region / Topic

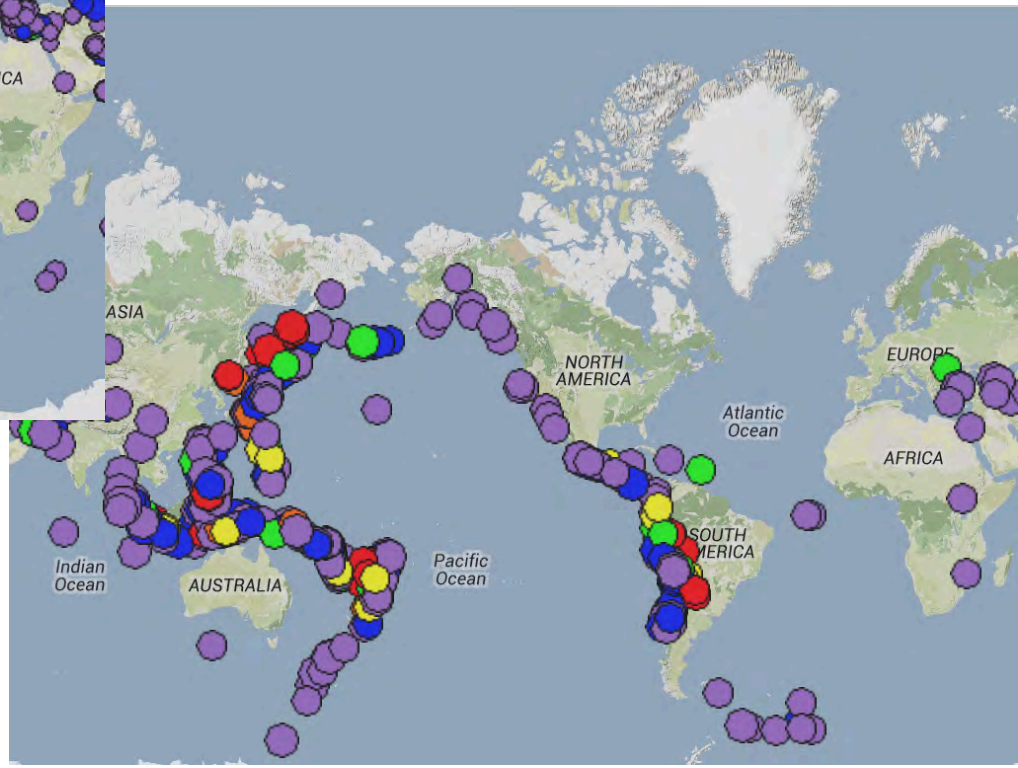
Open as: Table 3D View

Share map:

Selected Lat/Lon Range:
73.63
-180.00 180.00
-75.14



500 earthquakes magnitude
1 – 6.9



500 earthquakes magnitude
7.0 – 9.5

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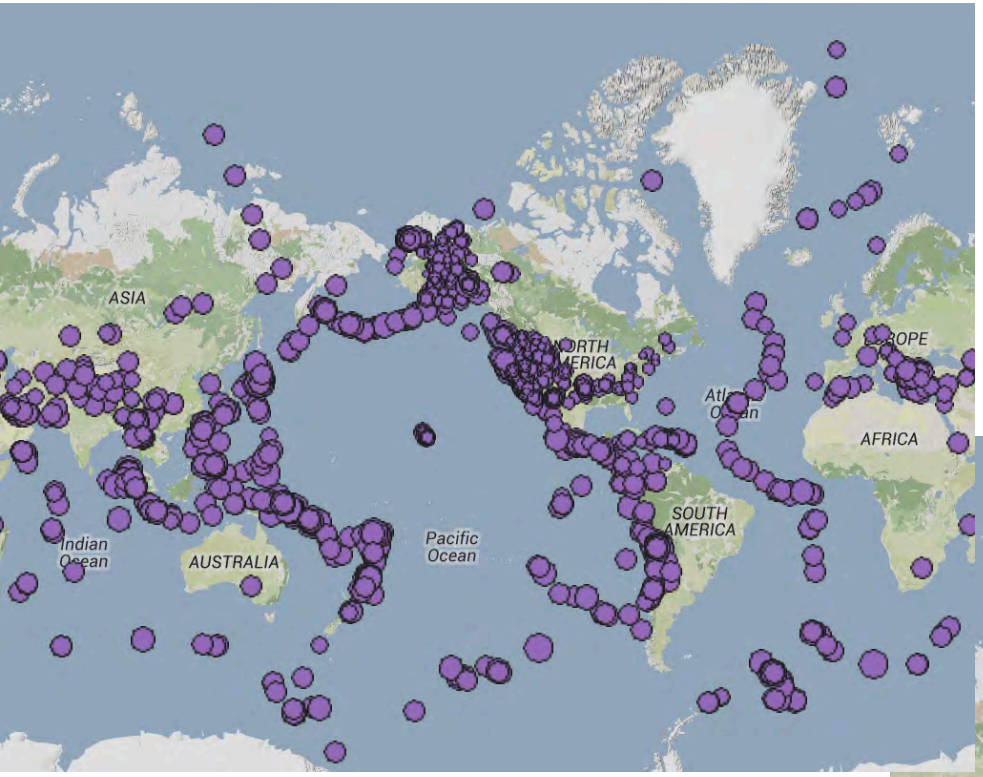
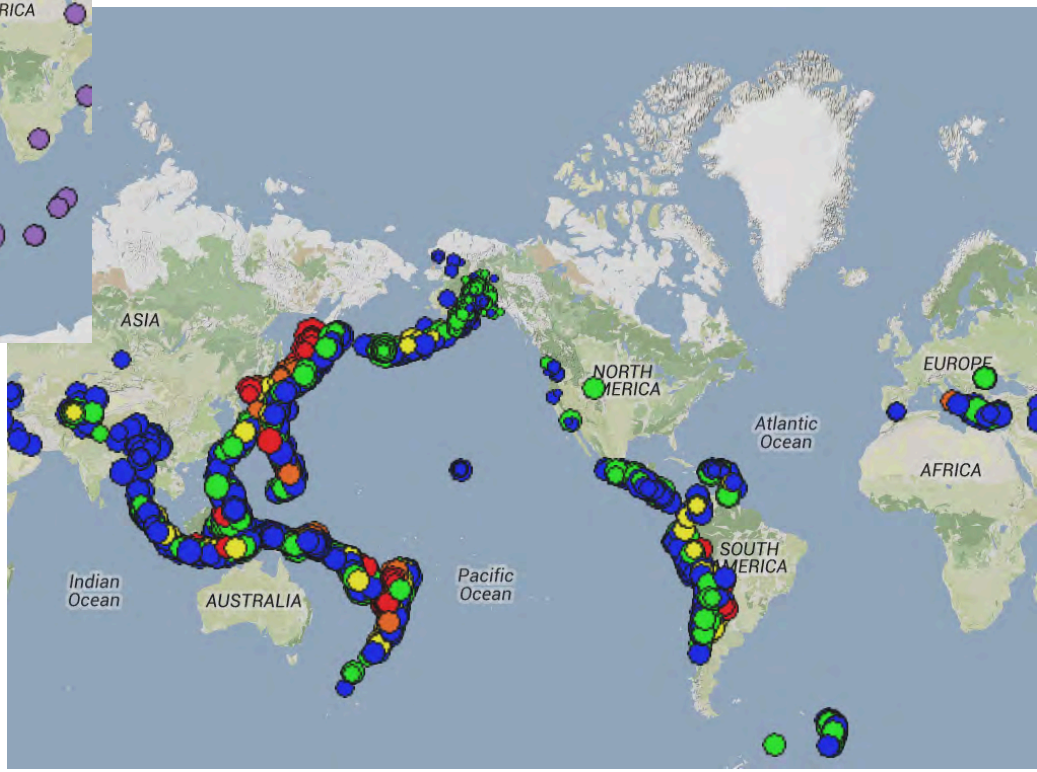
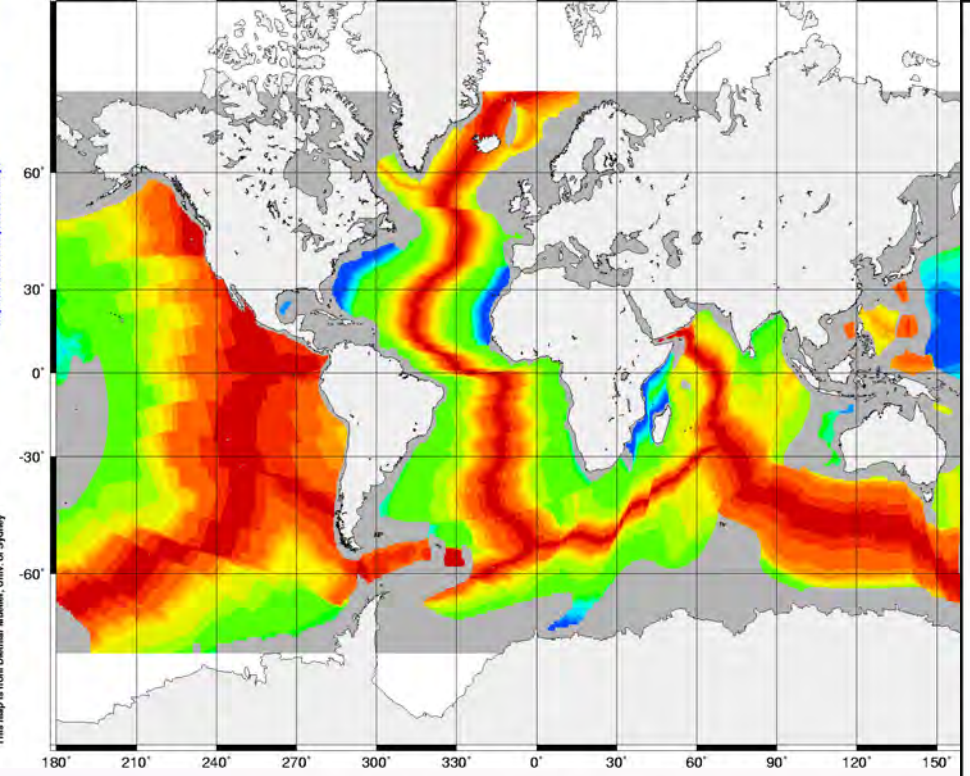
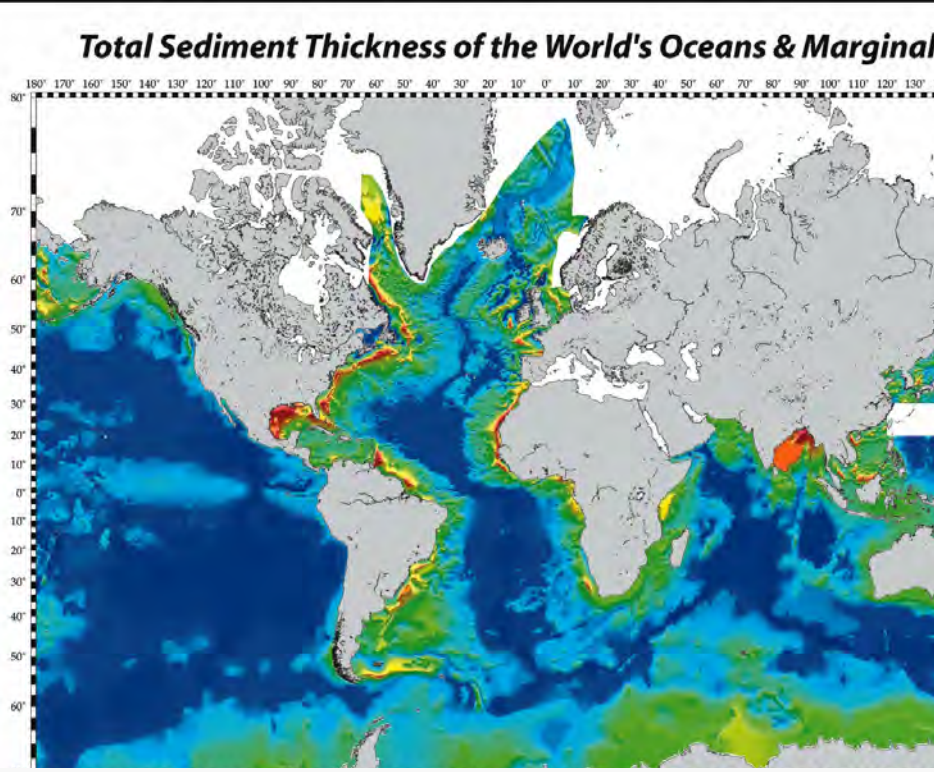


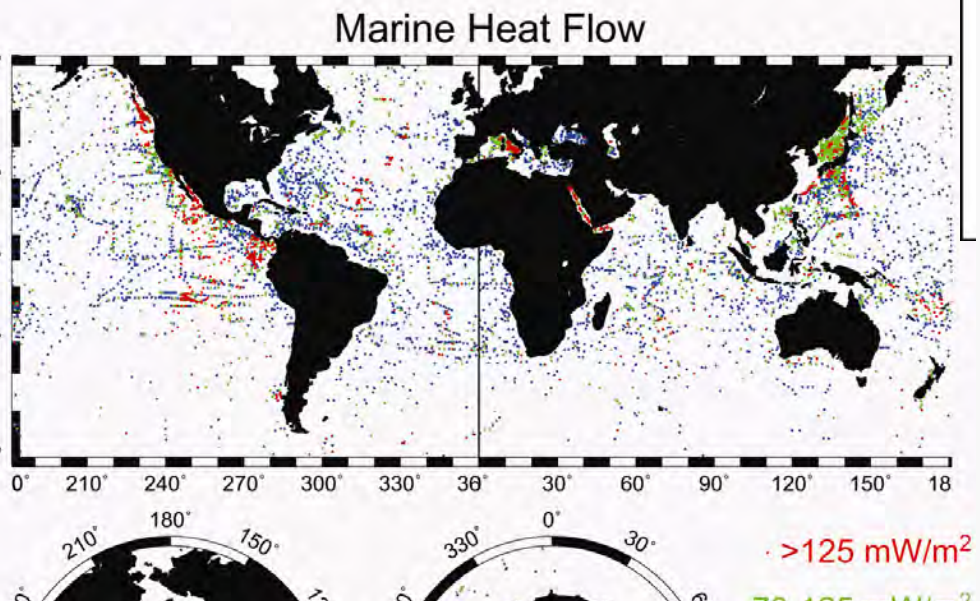
500 earthquakes
0-33 km deep

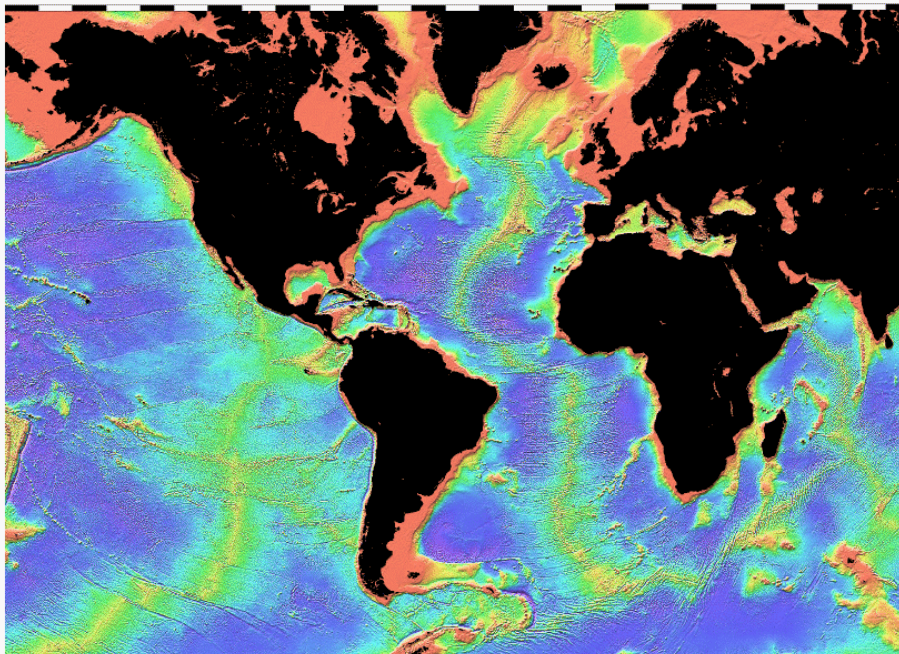


500 earthquakes
40-900 km deep


60°
30°
0°
-30°
-60°
180° 210° 240° 270° 300° 330° 0° 30° 60° 90° 120° 150°


Total Sediment Thickness of the World's Oceans & Marginal


Marine Heat Flow
0° 210° 240° 270° 300° 330° 360° 30° 60° 90° 120° 150° 18
180° 210° 150° 240° 120°
330° 0° 30° 300° 60°
>125 mW/m2
70-125 mW/m2



A verse in "geopoetry"

Harry Hess
1906-1969

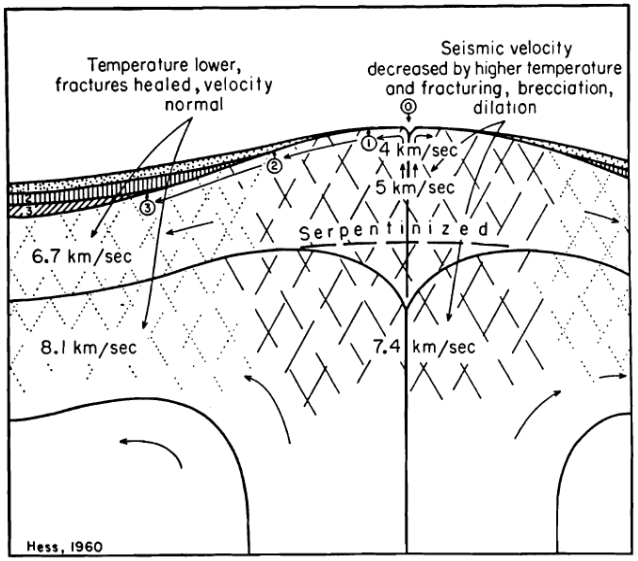


Figure 7. Diagram to represent (1) apparent progressive overlap of ocean sediments on a mid-ocean ridge which would actually be the effect of the mantle moving laterally away from ridge crest, and (2) the postulated fracturing where convective flow changes direction from vertical to horizontal. Fracturing and higher temperature could account for the lower seismic velocities on ridge crests, and cooling and healing of the fractures with time, the return to normal velocities on the flanks.

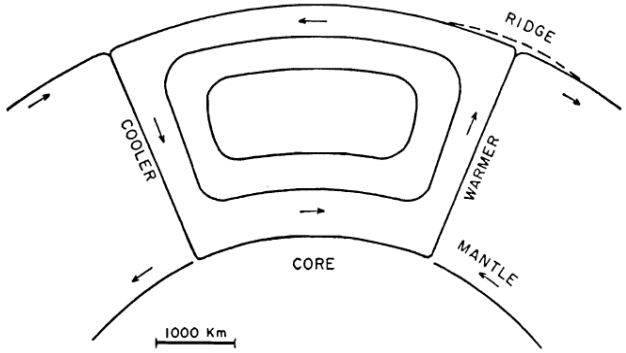
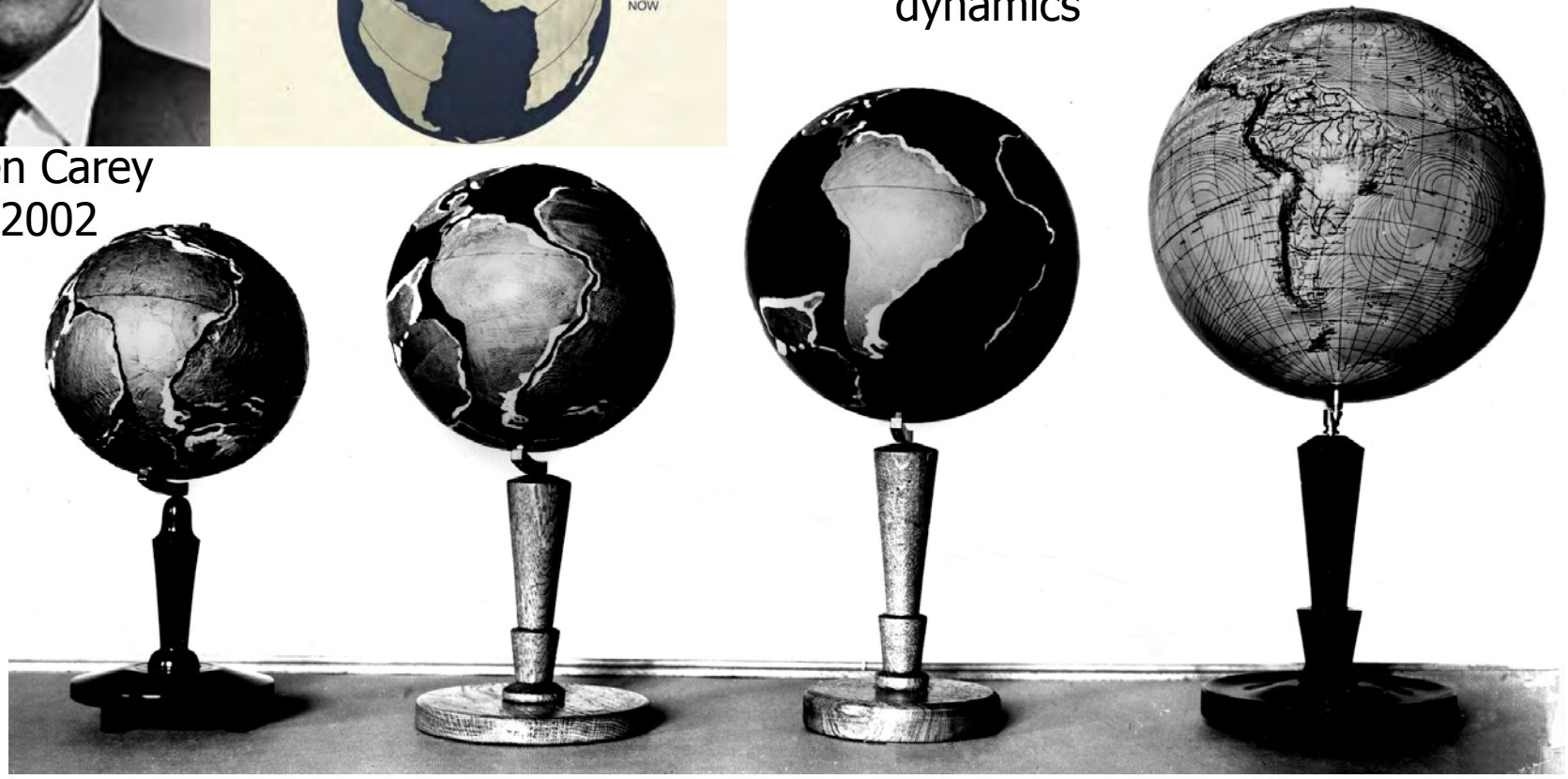


Figure 8. Possible geometry of a mantle convection cell

S. Warren Carey
1911-2002

Neal Adams:
http://www.youtube.com/watch?v=oJfBSc6e7QQ

J. Martin Herndon (2005):
Whole earth decompression dynamics



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Advantages of historical case studies

1. Builds context around content
2. Exemplifies science-in-the-making
3. Conveys facets of the nature of science
4. The controversy has essentially been resolved

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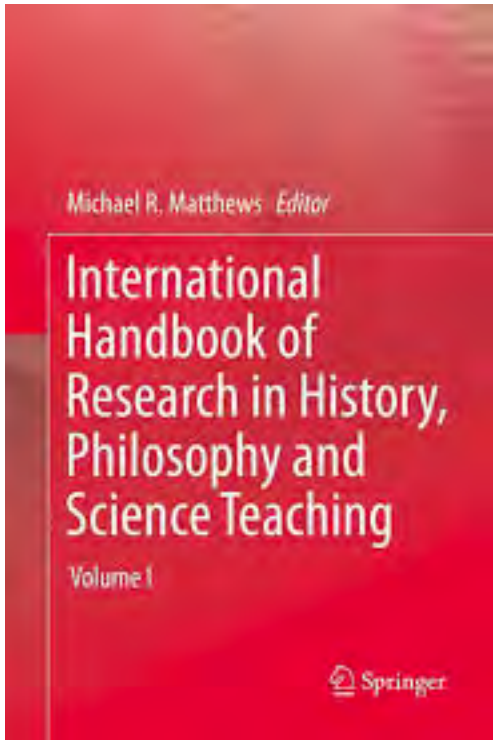
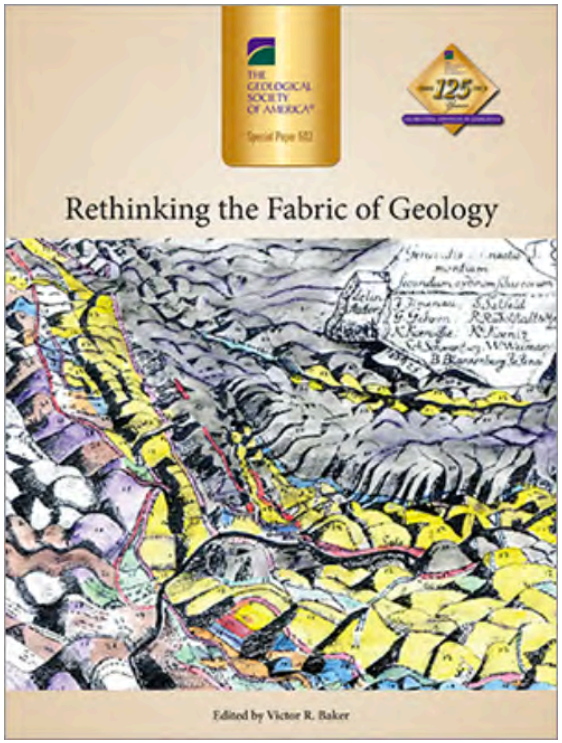
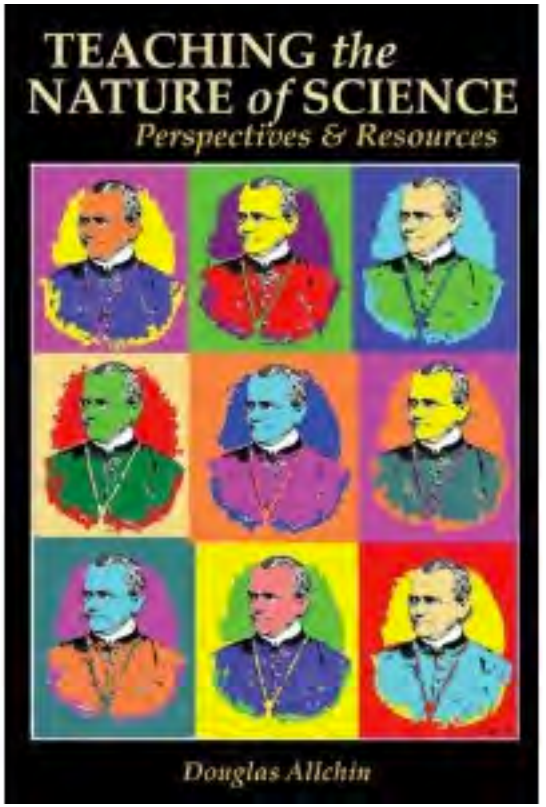
Resources for teaching with history







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