GY 112: Earth History

The Proterozoic Part 1
Lectures 18/19: Tectonics

Instructor: Dr. Douglas W. Haywick
Last Time

1) The Early Atmosphere
2) The Oceans and Hydrosphere
3) The Change
Earth’s Early Atmosphere

4.1 GA:
\[ \text{N}_2; \text{HCl}; \text{SO}_2; \text{CO}_2; \text{CH}_4; \text{NH}_3; \text{NO}_2; \text{H}_2\text{O} \]

No…. \( \text{O}_2 \)
Earth’s Hydrosphere

• All water on, in and over the Earth is recycled via the hydrologic cycle
Ozone

UV radiation in the upper atmosphere makes \textit{ozone}

\[ 2H_2O + UV \rightarrow H_2 + O_2 \]

\[ 2O_2 + UV \rightarrow O_3 + O \]
Oxygen

Cyanobacteria (e.g., the microorganisms comprising stromatolites) and photosynthesis made oxygen starting at least 3.865 GA ago..

\[
6\text{CO}_2 + 6\text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 \text{ ("sugar") } + 6\text{O}_2
\]
Oxygen

The atmosphere became oxidizing by 1.8 GA and reached near current levels by the Ordovician.

http://www.biologie.uni-hamburg.de/b-online/ge42/01.jpg
Today’s Agenda

Proterozoic Part 1: Tectonics

1) The Proterozoic time frame
2) Paleogeography
3) Tectonics (Wopmay Orogeny)
4) The Wilson cycle
5) The Trans-Hudson Orogenic Belt
6) The Grenville Orogeny

(Web Lectures 18 and 19)
The Proterozoic Eon

<table>
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<tr>
<th>Eon</th>
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<tbody>
<tr>
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<td>550 MA to 0 MA</td>
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<tr>
<td><strong>Proterozoic</strong></td>
<td><strong>2.5 GA to 550 MA</strong></td>
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**Platform:** younger (550 MA-2.5 GA) sedimentary rocks

http://mmsd1.mms.nrcan.gc.ca/efab/images/slide1canMap_e.gif
The Proterozoic Eon

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<td>900 MA to 550 MA</td>
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<tr>
<td>Mesoproterozoic</td>
<td>1.6 GA to 900 MA</td>
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<tr>
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• Paleo- old
• Meso- middle
• Neo- new
Proterozoic Paleogeography

Neoproterozoic 650 MA

- This is about as far back as we can go with detailed paleogeography
But we can “guestimate” back to about 1 GA.
Recall: Archean Tectonics involved differentiation of the Earth’s crust. Volcanoes, plutons and stretching of the crust, but possibly limited to no “ripping”.

Translation: As far as we can tell, there was no modern plate tectonics during the Archean.
Modern Plate Tectonics

- 7 major lithospheric plates
Modern Plate Tectonics

- Rigid lithospheric plates “float” atop ductile asthenosphere
Modern Plate Tectonics

- Where they make contact, you get serious geology (earthquakes, volcanoes, mountain building)
But this type of tectonics may not have always occurred.

The first evidence of divergent and convergent plate tectonics was during the Paleoproterozoic (2.1 Ga) in the Slave Province of the Canadian Shield.
Proterozoic Tectonics

- But this type of tectonics may not have always occurred.

- The first evidence of divergent and convergent plate tectonics was during the Paleoproterozoic (2.1 GA) in the Slave Province of the Canadian Shield.
Proterozoic Tectonics
Proterozoic Tectonics

Coronation Geosyncline
Proterozoic Tectonics

- Coronation Geosyncline
- Wopmay Orogen
Proterozoic Tectonics

- Coronation Geosyncline
- Wopmay Orogen
- Bathurst Aulocogen
Proterozoic Tectonics

- Coronation Geosyncline
- Wopmay Orogen
- Bathurst Aulocogen
- Athapuscow Aulocogen
Proterozoic Tectonics

• A paleogeographic reconstruction of the Coronation Geosyncline 2.1 GA would look like this:
Proterozoic Tectonics

- Which indicates that the Earth’s crust “rifted”, flooded with seawater and deepened over time.
• The Coronation Geosyncline therefore represents the opening of an ocean basin (i.e., a new ocean formed). But…
Proterozoic Tectonics

- Linear trenches also opened up.
Proterozoic Tectonics

- Linear trenches also opened up.
- They were mostly filled with coarse gravel and breccia (phase 1 fill in the Coronation Geosyncline)
Proterozoic Tectonics

• Linear trenches also opened up.

• They were mostly filled with coarse gravel and breccia (phase 1 fill in the Coronation Geosyncline)

• Ternary rifting patterns
• In any triple junction, one of the “arms” will become a failed rift or an Aulcogen. Two will continue to spread into an ocean.
Proterozoic Tectonics

- The best modern example of a “failed arm” is the East African Rift
Proterozoic Tectonics

• But the Coronation Geosyncline ocean did not last a long time.
Proterozoic Tectonics

- But the Coronation Geosyncline ocean did not last a long time.
- Granite was emplaced along the western side around 1.8 GA...
Proterozoic Tectonics

- But the Coronation Geosyncline ocean did not last a long time.

- Granite was emplaced along the western side around 1.8 GA...

  ...indicating a plate collision with another continent.
Proterozoic Tectonics

- This mountain-building event is called the Wopmay Orogeny
Proterozoic Tectonics

So what hit us?
Proterozoic Tectonics

So what hit us?

- The culprit was Australia seen here fleeing the scene of the accident about 500 MA after the incident.
The Wilson Cycle

- Oceans are created when plate tectonics results in rifting
• But the Wopmay Orogeny demonstrates that not only do ocean open up, they can also close back up again (Subduction)
The Wilson Cycle

- And sometimes they repeat this cycle more than once (e.g., the Atlantic Ocean)
• This is now called the **Wilson Cycle** in honor of J. Tuzo Wilson who first suggested it for the Atlantic Ocean.
Other Proterozoic Orogenies

**Orogeny**: A mountain building event (mostly collision and subduction, occasionally transform motion, but doesn’t require continent-continent collisions)

Note: Most mountain building episodes (regardless of the actual process are given specific names)

e.g.: the **Wopmay Orogeny**
Other Proterozoic Orogenies

Starting in the Paleoproterozoic, orogenies became very common around the world.
Trans-Hudson Orogeny

2.0-1.8 GA
Trans-Hudson Orogeny

Modern Island Arcs
Grenville Orogeny

1.0 GA

1.3 - 1.0 Ga

Karlstrom, K.E. et al., 1999
Grenville Orogeny

1.0 GA
Grenville Orogeny

1.0 GA

[Diagram showing geological features and processes at 1.0 GA and the present day erosional surface.]
Grenville Orogeny

1.2 Ga
Superior Province
Rae Province
Nain Province

Uranus Ocean
Uranus ocean destroyed ca. 1.0 Ga

500 Ma

Lapetus Ocean

Lapetus Ocean destroyed ca. 500-935 Ma

Europe

Africa

Atlantic Ocean = 800 Ma → Present
Today’s Homework

1. Time line version 1 due NOW
2. Study for Lecture test 2 (March 23, Tuesday after spring break)

Next Time

1. Proterozoic climate (a “cool” lecture)
GY 112: Earth History

Lectures 18/19: Proterozoic Tectonics

Instructor: Dr. Doug Haywick
dhaywick@southalabama.edu

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