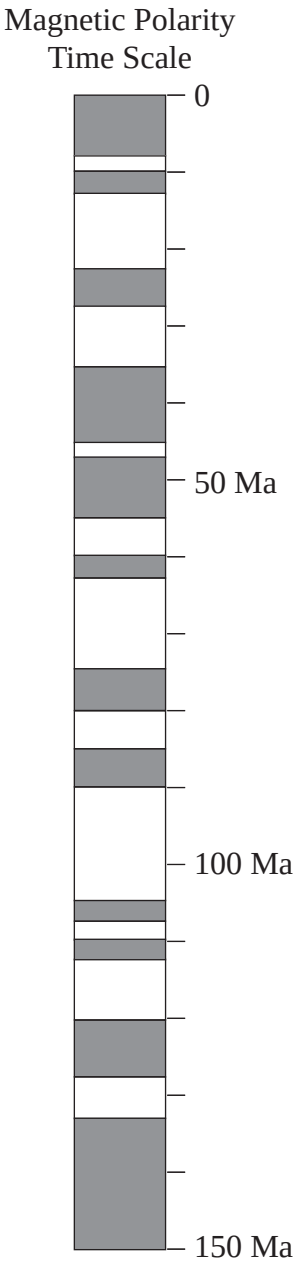
"Geoworld" Plate Tectonics Lab

Purpose: To better understand the principles of the plate tectonics theory by applying them to the past, present and future analysis of a theoretical planet.

Reading Assignment: Any passages on plate tectonics in your textbook.

Introduction

During this lab exercise, we will analyze the plate tectonics of part of a mythical planet called Geoworld; a tectonic map of the area is shown on p. 9. Geoworld has a plate tectonics system just like ours on Earth, only Geoworld is flat instead of spherical. In answering the questions below, you may assume that the movement rates for plates (both relative and absolute) are constant throughout the time between your past and future reconstructions (they were, however, quite different at one time - see Part 1, A., questions 6 and 7). **All questions are in bold face. Please put your answers in any blanks provided.**



Part 1: Analysis of the Present State of Geoworld

A. Sea Floor Magnetic Anomalies

Geoworld has a magnetic field aligned in a north-south direction. The polarity of this field reverses at random intervals through time, just as the one on Earth does. The history of polarity of the magnetic field is well known for the past 150 million years and is shown by the adjacent magnetic polarity time scale. Shading represents normal polarity (the magnetic field points north) while white represents reverse polarity (the magnetic field points south).

Detailed aerial and ship-board magnetic surveys have been conducted over the oceans of Geoworld. Parts of the sea floor have an extra strong magnetic field while other parts have an extra weak magnetic field. Just as on Earth, the areas with anomalously strong magnetic fields are composed of rocks that are magnetized with the same polarity as the current field while areas with anomalously weak magnetic fields are composed of rocks that are magnetized with the opposite polarity as the current field. Portions of the sea floor with an anomalously strong magnetic field are shaded; portions of the sea floor with an anomalously weak magnetic field are unshaded.

Note that the magnetic anomalies form a striped pattern on the map of Geoworld. Note also that the pattern in the Elrond Sea is symmetrical while that in the Aragorn Ocean is asymmetrical. This is because there is an active spreading ridge in the Elrond Sea but not in the Aragorn Ocean. The center of symmetry in the Elrond Sea is right along the spreading ridge.

1. **On the map on page 9, highlight the mid-ocean ridge in the Elrond Sea and label it the <u>Hobbit Ridge</u>.**

2. **Draw a diagram <u>and explain</u> the origin of the striped magnetic anomaly pattern visible in the Elrond Sea.**

3. **The pattern of positive and negative magnetic anomalies in the Elrond Sea can be correlated with the pattern of normal and reversed magnetism on the magnetic polarity time scale. Based on this correlation, how many million years (m.y.) ago did sea floor spreading begin in the Elrond Sea?**

Spreading Began _____ m.y. ago

4. **Using the magnetic anomaly pattern in the Elrond sea, determine the 1/2-spreading rate on the Hobbit Ridge (i.e., determine how fast the Frodo continent is moving away from the Hobbit ridge). Give your answer in mm/y (millimeters per year). <u>Show your equations and explain where each number came from</u>.**

Useful Information: 1 cm (10 mm) on the map = 400 km on Geoworld
1 mm/y = 1 km/m.y. (kilometers per million years)
distance = rate x time, rate = $\frac{\text{distance}}{\text{time}}$, time = $\frac{\text{distance}}{\text{rate}}$

1/2 spreading rate = _____ mm/y

5. **What is the full spreading rate (in mm/y) of the Hobbit Ridge? (i.e., how fast are the Bilbo and Frodo continents moving away from each other)? <u>Show your equations and explain where each number came from.</u>**

<u>Full</u> spreading rate = ____ mm/y

6. **Using the magnetic anomaly patterns in the Aragorn Ocean, determine when sea floor spreading started to form the Aragorn Ocean crust (remember, spreading is not actively going on now but it was at one time).**

Spreading Started ____ m.y. ago

7. **<u>At the time that active sea-floor spreading was occuring in the Aragorn Ocean</u>, at what rate was new sea-floor being created? (<u>Think</u>: is this related to the full spreading rate or the half spreading rate)? <u>Show your equations and explain where each number came from</u>.**

Rate of formation of Aragorn Ocean crust = ____ mm/y

B. Plate Boundaries

1. **There are two plate boundaries on the map. You already highlighted one of them in Part 1, A. 1. above. Highlight the other boundary also.**

2. **Give one example of each of the following types of plate boundaries on Geoworld (Note: the boundary between two plates can vary in type from place to place).**

   Divergent boundaries _____

   Convergent boundaries _____

   Transform boundaries _____

3. **How many lithospheric plates are there in all?** _____

C. Cross-Section

Make a schematic cross-section of Geoworld along A-A'. Draw it in the box provided at the bottom of the map on page 9. Show the entire thickness of the lithosphere and part of the asthenosphere. Label the crust, mantle lithosphere and asthenosphere.

D. Transform Faults

There are several transform faults in the Elrond Sea. The only parts of these faults that are presently active are the parts between the segments of the Hobbit Ridge.

1. **Using arrows, show the sense of motion on each of the active transform faults on the map.**

2. **In the space below, draw a diagram and explain why the sense of motion on a transform fault is the way it is.**

E. Earthquakes

1. **Describe three places on the planet of Geoworld where you would expect large numbers of earthquakes.**

   a. _____

   b. _____

   c. _____

2. **The vast majority of earthquakes are caused by movement on faults. What types of faults would you expect at each location you described above (thrust, normal, strike-slip)?**

   a. _____

   b. _____

   c. _____

3. **For each location described above, record whether the earthquakes will have deep foci and/or shallow foci.**

   a. _____

   b. _____

   c. _____

F. The Origin of the Volcanic Islands

1. **The Galadriel Islands, Gandalf Islands and Gollum Island are all made of volcanic rocks. What are the difference in tectonic origin among these three groups of islands?**

2. **What type of volcanic rock would you expect Gollum Island to be composed of and why?**

G. Hot-spots and Absolute Movement Rates

1. Absolute motion of the Aragorn Ocean and the Bilbo Continent

Notice the Gandalf Islands. They are analogous to the Hawaiian Islands on Earth. They form a linear chain that originated by the migration of the plate over a mantle hot spot. Mantle hot spots are assumed to be fixed relative to the center of the planet.

All of the Gandalf islands are volcanic in origin but the easternmost and largest island--which is sitting directly over the hot spot--is the only one with active volcanoes on it. The rocks on the westernmost island have been dated by radiometric methods at 32 m.y.

Measure the distance between the centers of the westernmost and easternmost Gandalf islands and use this information to calculate the absolute movement rate (in mm/y) of the Aragorn Ocean (and the Bilbo Continent, which is connected to it). Show your equations and explain where you got each of your numbers.

Helpful hint: Pay no attention to the magnetic anomalies when answering this question.

Absolute movement rate of the Aragorn Ocean = _____ mm/y

2. **From careful measurements taken by satellites, we know that the Sauron Trench and the Galadriel Islands are fixed in position. At what speed (in mm/y) is the Bilbo Continent moving toward the Galadriel Islands?**

Speed of Bilbo Continent relative to Galadriel Islands = _____ mm/y

3. **In what direction and how fast (in mm/y) is the Frodo Continent moving relative to the Galadriel Islands? <u>Show your equations and explain where each number came from</u>.**
Hint: Assign positive and negative signs to the different directions of motion.
Specific suggestion: make all plate motion to the right (east) have positive velocities and make all plate motion to the left (west) have negative velocities.

Direction and speed of Frodo Continent relative to Galadriel Islands = _____ mm/y

toward the _____.

4. **Is the Hobbit Ridge moving? If so, in what direction and how fast (in mm/y) is it moving relative to the Galadriel Islands? <u>Show your equations and explain where each number came from</u>.**

Direction and speed of Hobbit Ridge relative to Galadriel Islands = _____ mm/y

toward the _____.

Part 2: Analysis of Geoworld in the Past

A. Using the map on p. 11, cut along the margins of the Elrond Sea and put the Bilbo and Frodo Continents back together in their original configuration, forming the Bilbo/Frodo supercontinent. The Misty Mountains and the Rivendell Mountains are fold-and-thrust mountains. The age of deformation in both mountain ranges is 200 million years before present.

How are the two mountain ranges related, if at all?

B. What type of plate tectonic event do they probably represent?

C. While the Elrond Sea has been opening, the Aragorn Ocean has been closing. Assuming that (1) no sea-floor spread has taken place in the Aragorn Ocean for at least 65 million years, and (2) subduction has been occurring for at least 65 million years, how wide was the Aragorn Ocean along A-A' at the time spreading started in the Elrond Sea? Use the Sauron Trench as the western boundary of the Aragorn Ocean. Show your equations and explain where each number came from.

Width of Aragorn Ocean along A-A' at the time spreading started in the Elrond Sea = _____

D. Move the Bilbo/Frodo supercontinent back to its original position at the time that spreading started in the Elrond Sea. You have now reconstructed the complete plate tectonic picture of the Geoworld planet at the time when spreading started in the Elrond Sea.

Tape or glue the cut-out pieces onto a blank page, carefully placing them in their correct positions for the reconstruction. Label the following:

1. **Bilbo/Frodo supercontinent**
2. **Aragorn Ocean**
3. **Sauron Trench**
4. **Galadriel Islands**

E. Make a schematic cross-section of your past reconstruction of Geoworld along A-A'. Show the entire thickness of the lithosphere and part of the asthenosphere.

Part 3: Analysis of the Future State of Geoworld

A. When will the Bilbo Continent and the Sauron Trench first collide? Show your equations and explain where each number came from.

Time of Collision = _____ m.y. from now

B. How wide will the Elrond Sea be at that time? Show your equations and explain where each number came from.

Width of Elrond Sea = _____ km

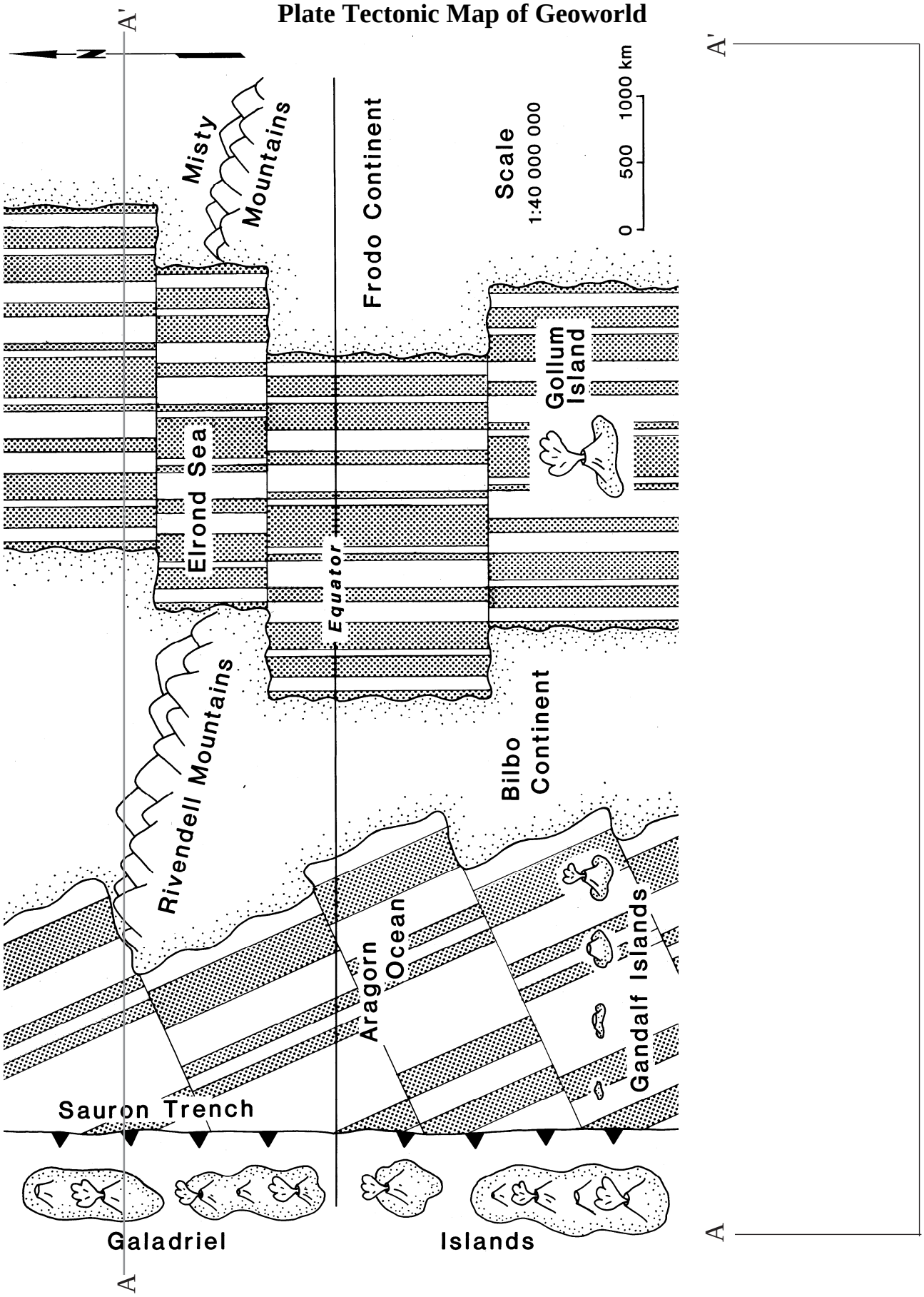
C. Cut out pieces as needed from the map on page 13 and use them to reconstruct the configuration of the plates for the time of the first collision of the Bilbo continent with the Sauron trench

Tape or glue the cut-out pieces onto a blank page, carefully placing them in their correct positions for the reconstruction. Label the following:

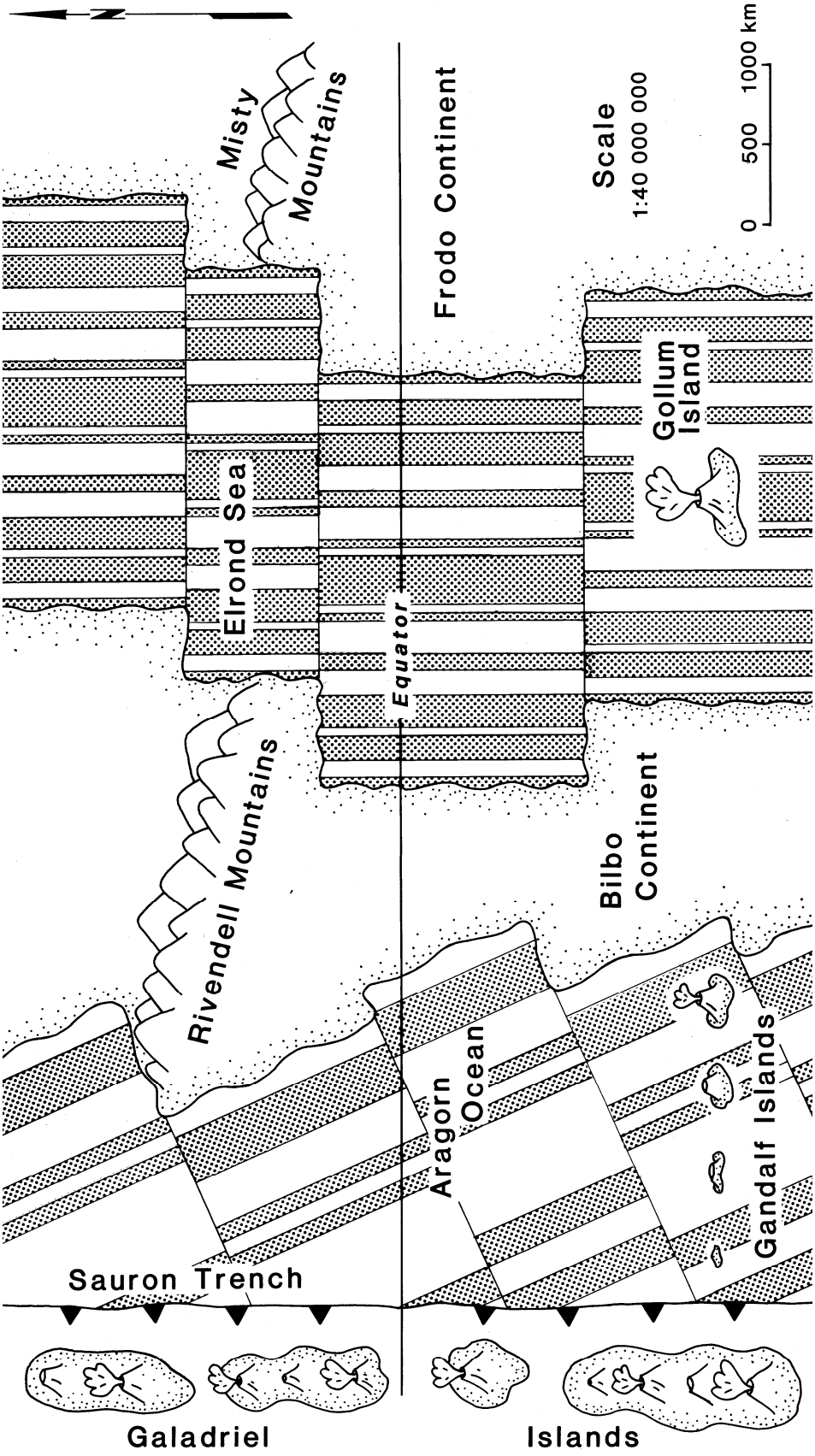
1. Galadriel Islands
2. Sauron Trench
3. Aragorn Ocean
4. Bilbo Continent
5. Hobbit Ridge
6. Elrond Sea
7. Frodo Continent

D. Make a schematic cross-section of your prediction for the future state of Geoworld along A-A'. Show the entire thickness of the lithosphere and part of the asthenosphere.

Plate Tectonic Map of Geoworld



Cut up this map to make past reconstruction of Geoworld.



Cut up this map to make future reconstruction of Geoworld.