Lab 2: Visualizing the Large-Scale Earth (35 points)

The ability to develop, analyze, and interpret large-scale diagrams and maps is a key skill for geoscientists. Figures, including some in your textbook, often sacrifice a physically accurate 1:1 scale in order to fit onto an 8.5 x 11 inch page. In the first half of this lab you will draw a detailed figure to scale and develop an interpretation. In the second half you will analyze and interpret the large-scale tectonic features from a topographic map of western North America. Turn this in at the end of the lab period or by the beginning of lab next week. Please include all your work!

1. Pie Diagram (60%)

The crust, lithosphere, and asthenosphere are thin in comparison to deeper zones of the Earth (mesosphere, outer core, and inner core). To investigate the true relative thickness and volumetric importance of these various layers, you will develop a cross-sectional diagram with no vertical exaggeration.

On the provided pie wedge, and using a millimeter-scale ruler and compass with a fine-tipped pencil, fill in a detailed structure of the earth (similar to Lillie Fig. 2.5, only as a wedge) at a scale of the radius of the earth to the radius of the pie wedge (6371 km:20 cm). Thus, for instance 1593 km:5 cm and so forth. Illustrate the boundaries described below exactly to scale, at the depths or radii indicated. Carefully name and label depths to all boundaries and zones on the diagram. It may be difficult to accurately draw some of the thinnest layers, so do your best! Key layer radii:

<table>
<thead>
<tr>
<th>Layer</th>
<th>Radius</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radius of Earth</td>
<td>6371 km</td>
</tr>
<tr>
<td>Radius of Inner Core</td>
<td>1221 km</td>
</tr>
<tr>
<td>Radius of Outer Core</td>
<td>3480 km</td>
</tr>
</tbody>
</table>

a. Draw the arc representing the boundary between the inner core and the outer core using the inner core radius.

b. Draw the arc representing the boundary between the outer core and the lower mantle using the outer core radius.

c. Draw the arc representing the boundary between lithosphere and asthenosphere at 150 km depth below the Earth’s surface.

d. At 350 km depth, draw the arc representing the boundary between the relatively soft portion of the asthenosphere and the relatively stronger portion of the asthenosphere.

e. At 700 km depth, draw the arc representing the boundary between the base of the asthenosphere and the deeper, more rigid portion of the mantle called the mesosphere.

f. On the left half of the wedge, draw an arc representing the boundary between the oceanic crust and the mantle portion of the oceanic lithosphere. This boundary is called the Mohorovičić discontinuity (Moho for short) and is within the oceanic lithosphere; it
separates the mafic oceanic crust of the lithosphere from the deeper mantle portion of the lithosphere called "lithospheric mantle". The average thickness of oceanic crust (excluding oceanic sediments deposited atop igneous basement) is 6 km.

**g.** On the right half of wedge, draw an arc representing the boundary between the continental crust and the mantle portion of the continental lithosphere. This boundary is also called the Moho, but in this case it separates the felsic continental crust of the lithosphere from the deeper lithospheric mantle. The average thickness of continental crust (excluding sediments above the basement) is 35 km.

**h.** Use the models of density and seismic wavespeed variations with depth found on the following pages to label reasonable values expected for the density, P-wavespeed, and S-wavespeed at the top and bottom of each major earth division that you have drawn. Where does the largest change in these three quantities occur? How do they change? Why?

**i.** Write a short summary (one or two paragraphs will be fine) of what you learned and mention anything that you found important or surprising from your completed diagram. Offer some general thoughts on what key physical/chemical changes occur as you descend into the Earth and how these relate to density and seismic wavespeed. Calculate the following quantities, report and discuss the results in your summary:

- % of Earth’s volume (km³) and mass (kg) made of continental crust (40% of all crust).
- % of Earth’s volume and mass made of lithosphere.
- % of Earth’s volume and mass in the core (inner core and outer core combined).
- % of Earth’s volume and mass in the mantle below the lithosphere.

Note: the formula for volume of a sphere is \( V = \frac{4}{3}\pi R^3 \), be mindful of unit conversions.

In your calculations, use the densities of 5.5 g/cm³, 2.67 g/cm³, 3.3 g/cm³, 4.5 g/cm³, 10.8 g/cm³ respectively for the whole earth, crust, lithosphere, lower mantle, and core.

Make sure to include your reasoning if you make any assumptions in the above calculations or estimations! Show your work!

**BONUS (2 pts.)** Explain why and how the asthenosphere-mesosphere transition occurs by 700 km depth. Give one specific example of how we know this.
2. Regional Tectonic Interpretation (40%)
Here you will analyze this shaded topographic map of the western United States. White shading represents the highest elevations. Bathymetry of the nearby ocean floor is shown. Use this map to identify and comment on the major tectonic features of the western United States and the adjacent ocean, which has been reworked significantly during the Mesozoic and Cenozoic and is the current focus of EarthScope, a major geophysical study of North America. On the attached blank map:

a. Identify and label the positions of the following features on the map: (1) lithospheric plates and their names, (2) plate boundaries, their types, and their names.

b. Draw X’s to represent zones of significant earthquake activity.

c. Draw Δ’s on current zones of volcanic activity.

d. Numerous geophysical experiments have studied western North America over the past several decades, providing observations of changes in the thickness of the crust and lithosphere and constraining how the mantle deforms beneath the continent. The results of some are given as examples in your text. Using the following conventions, shade on the blank map in red regions where you would expect thinner than average crust and lithosphere, and in blue regions where you would expect thicker than average crust and lithosphere.

General rule:
- High elevation, extended – thin
- High elevation, compressed – thick
- Low elevation, continental margin – thin
- Low elevation, old continent – thin/thick

Briefly explain how thin or thick lithosphere relates to changes in elevation throughout the central part of the map region, and what processes in the Mesozoic and Cenozoic could have lead to the thickening and thinning of the lithosphere. This does not need to be a full geologic history of western North America, we just want to see a general awareness for the tectonic framework of the region.
Problem 1 Cross-Section Wedge