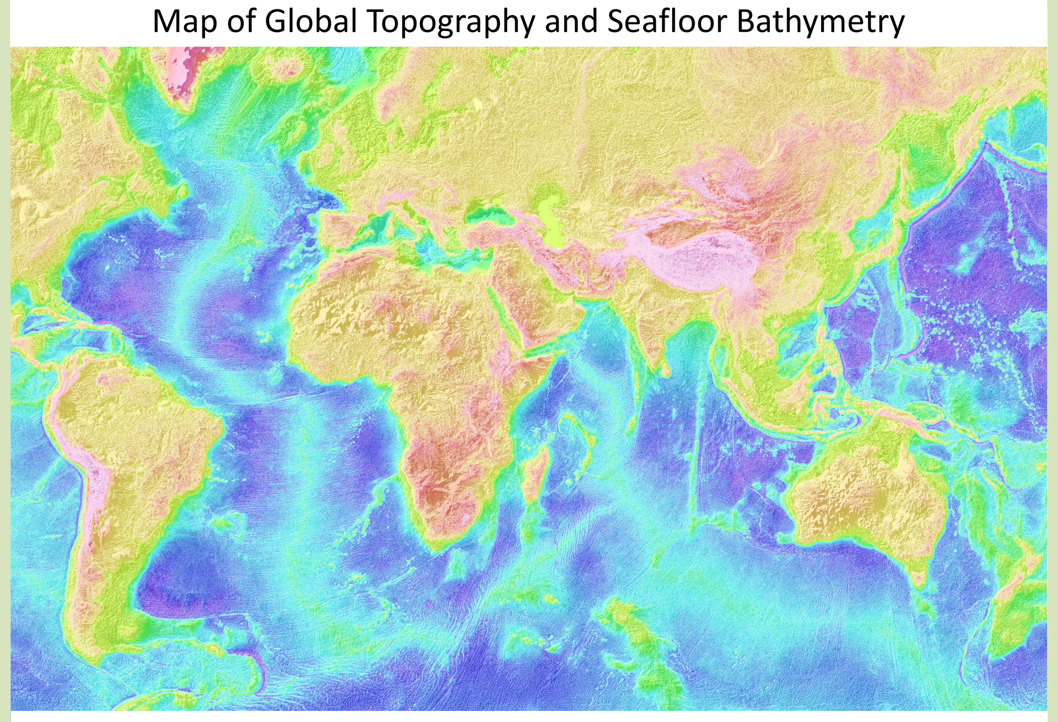
Making Observations about Mid-Ocean Ridges and Associated Rocks

Jamie Levine, Appalachian State University, levinejs@gmail.com

<u>ACTIVITY OVERVIEW</u>: This is an in-class activity that can be used in a tectonics course at a variety of different levels. Depending on the level, the instructor may choose to leave out or spend more time on specific sections. In this activity students gain experience working in pairs/small groups, making observations about mid-ocean ridges based on Google Earth images, and applying these observations to make conclusions about varied spreading rates. Students also practice identifying typical upper mantle and oceanic crustal rocks and compare and contrast rock densities to work on determining an appropriate sequence of rocks found at a mid-ocean ridge.

Map of Global Topography and Seafloor Bathymetry



by Walter H. Smith and David T. Sandwell, 1997 images on NOAA website
http://www.ngdc.noaa.gov/mgg/image/walter/AtlInd.jpg

I put up this map and ask students to make observations about bathymetric/topographic features that are visible. When students mention the mid-ocean ridges, I ask them to make as many observations (individually) as possible from this map. As a class we discuss these observations and I record them on the board.

After a preliminary discussion of features associated with mid-ocean ridges, I have the students form groups of 2-3 and make observations about similarities and differences between the Mid-Atlantic Ridge (MAR) and East Pacific Rise (EPR), based on Google Earth images. Initially I show the students images on a global scale and then I progressively zoom in, so that students are able to see features on a variety of scales. Students spend 2-3 minutes on each mid-ocean ridge. I also ask students to discuss with their group members some potential causes for the differences they noticed. After students have constructed their lists of observations, we discuss as a class and I record similarities and differences between each location, and potential causes of differences between the two locations.

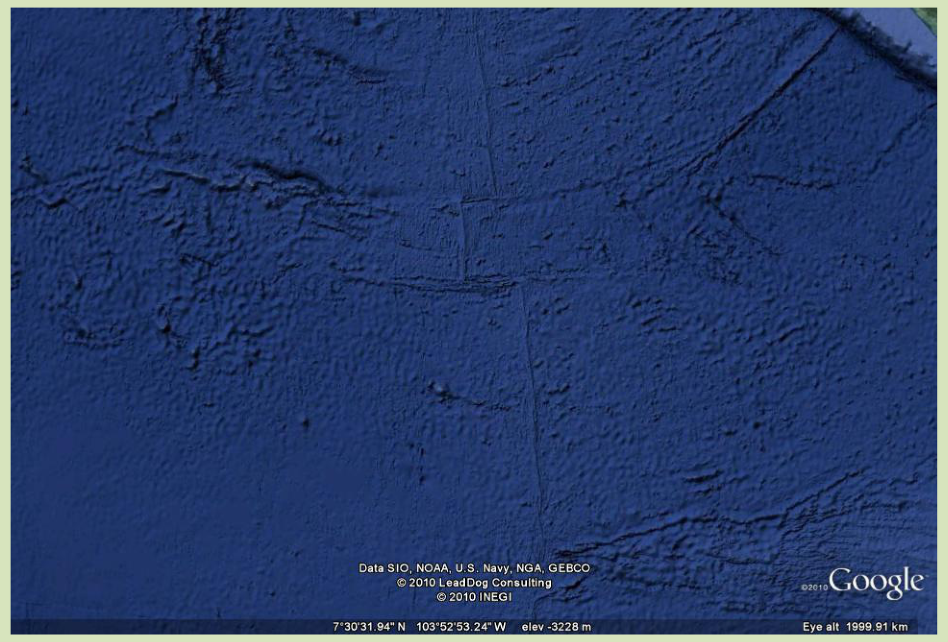
Google Earth Mid-Atlantic Ridge (MAR) Images

19°39' 01" N, 44°14'22" W

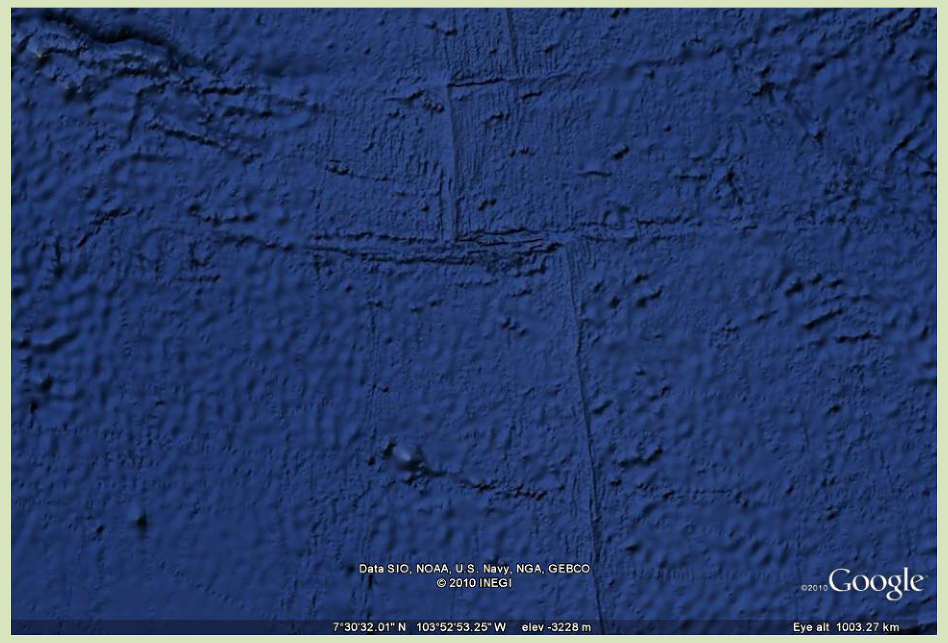
Google Earth East-Pacific Rise (EPR) Images

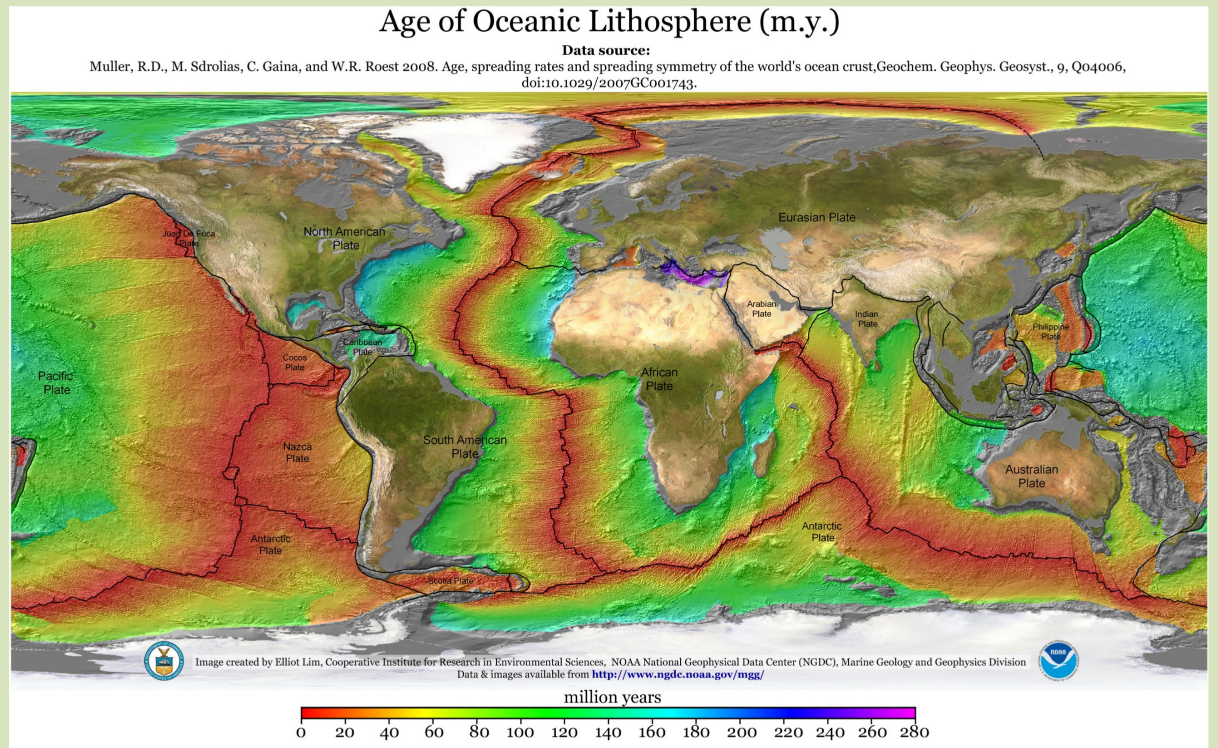
7°30' 31" N, 103°52' 53" W

Observations at the global scale are likely to be restricted to transform faults and potentially that the MAR appears more prominent.



At these scales (eye altitudes of 1000-2000 km) students notice that the MAR is a bathymetric low, whereas the EPR is a high. Additional observations may include differing abundance of transform faults and seafloor bathymetry adjacent to the ridges.





After students have come up with causes for differences between the MAR and the EPR, I show this image of the age of oceanic lithosphere. (Depending on the structure of your course, you may need to pause to discuss magnetic anomalies, but I have usually discussed them already.) Regardless of whether students have proposed fast vs. slow spreading rates as a cause for the differences seen between the MAR and the EPR, this image will allow all students to see that spreading rates vary across mid-ocean ridges.

From Moores and Twiss, 1995

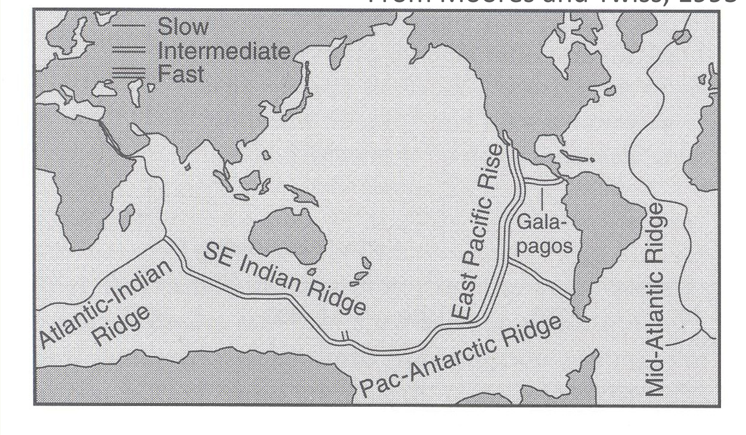
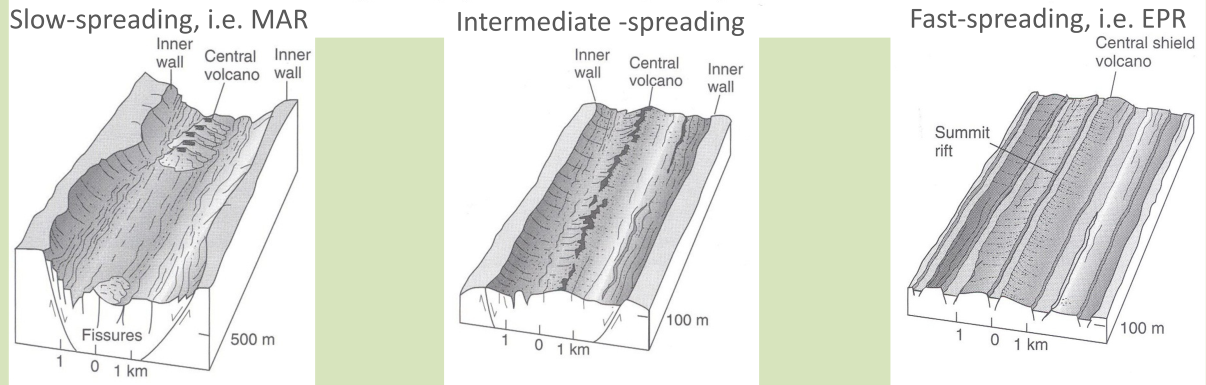


Figure 5.18 Map of world's ridges, classified according to spreading rate. *(After Macdonald, 1982)*



Once we have established that mid-ocean ridges do not all spread at the same rate, I ask the students to evaluate the observations they made from Google Earth in the context of spreading rate. I use these images from Moore and Twiss (1995) as another view of the structure of mid-ocean ridges. Although Google Earth shows some features very well, these sketches provide an excellent 3-D perspective. The cross-sectional views below (from Macdonald, 1982) provide a much clearer view of topographic differences across the ridges. The main differences that students usually pick up on are the topographic differences between slow and fast spreading ridges and the increased abundance of faults at the MAR. One key similarity that is better observed from the sketches and topographic profiles is that regardless of spreading rate, there is a local topographic high right at the ridge axis.

With these observations in mind, I split students into different small groups. I ask them to spend 5 minutes coming up with mechanisms to explain why spreading rate would affect the structure of the ridge, focusing on the processes that are occurring. After the small group discussion, I compile a list of possible mechanisms on the board. Ideally groups will have suggest magmatism and faulting as the 2 main controls on mid-ocean ridge structure. If they have, we discuss the competition between the processes; if not I come back to this topic at the end.

From Macdonald, 1982

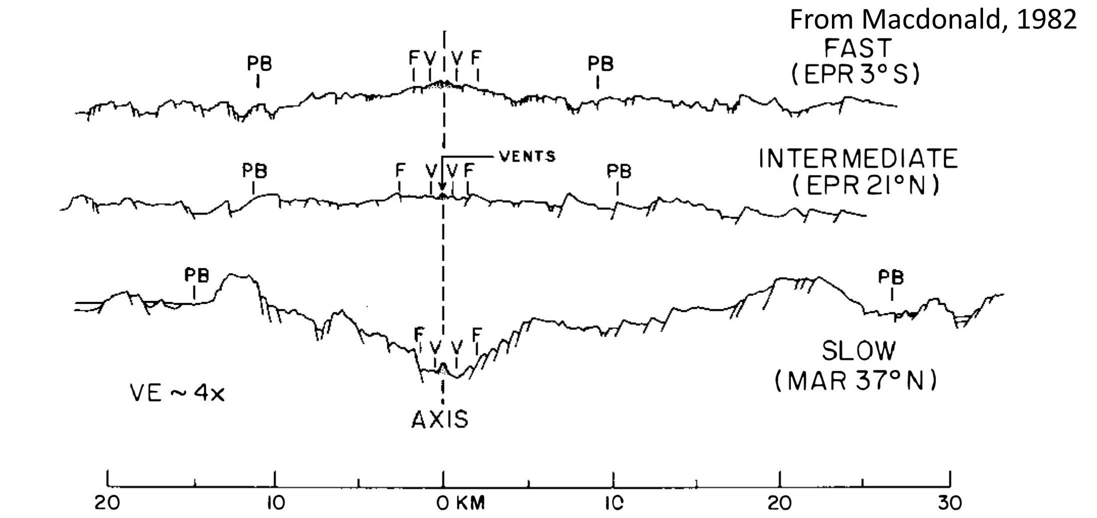


Figure 2 High resolution deep-tow profiles
zone of fissuring
Active faulting occurs up to 10–30 km off axis. Data from Lonsdale (1977), Normark (1976), Shih (1980), Macdonald et al (1975), and Macdonald & Luyendyk (1977).

Seismic structural models of oceanic crust

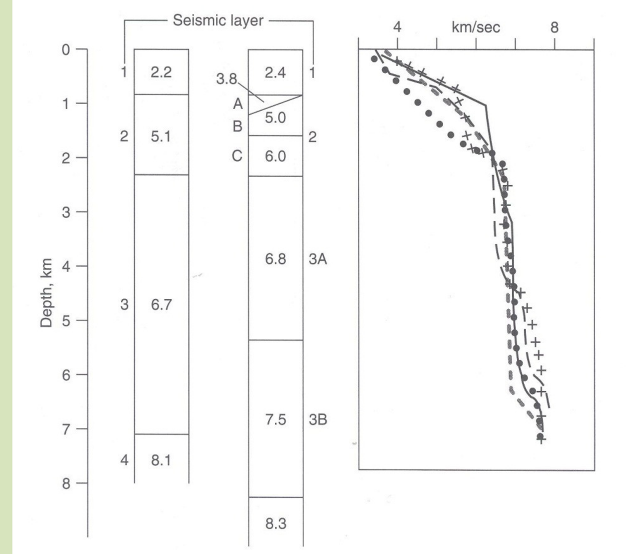


Figure 5.23 From Moores and Twiss, 1995; After Christiansen and Salisbury, 1975; Rosendahl, 1976; McClain, 1981; and Atallah, 1986

At this point, I switch gears and talk briefly about other ways that we can gain information at mid-ocean ridges, including seismic data and ophiolite sequences. After a very brief overview of seismic data, I give students (in small groups), several ocean lithospheric rocks to study. In the past I have used either harzburgite or dunite, gabbro, basalt and chert. However, any ultramafic rock and any seafloor sediment can be used. I ask the students to arrange the rocks in order of decreasing density and if possible to identify them. Rocks should be roughly the same size for accurate comparison.

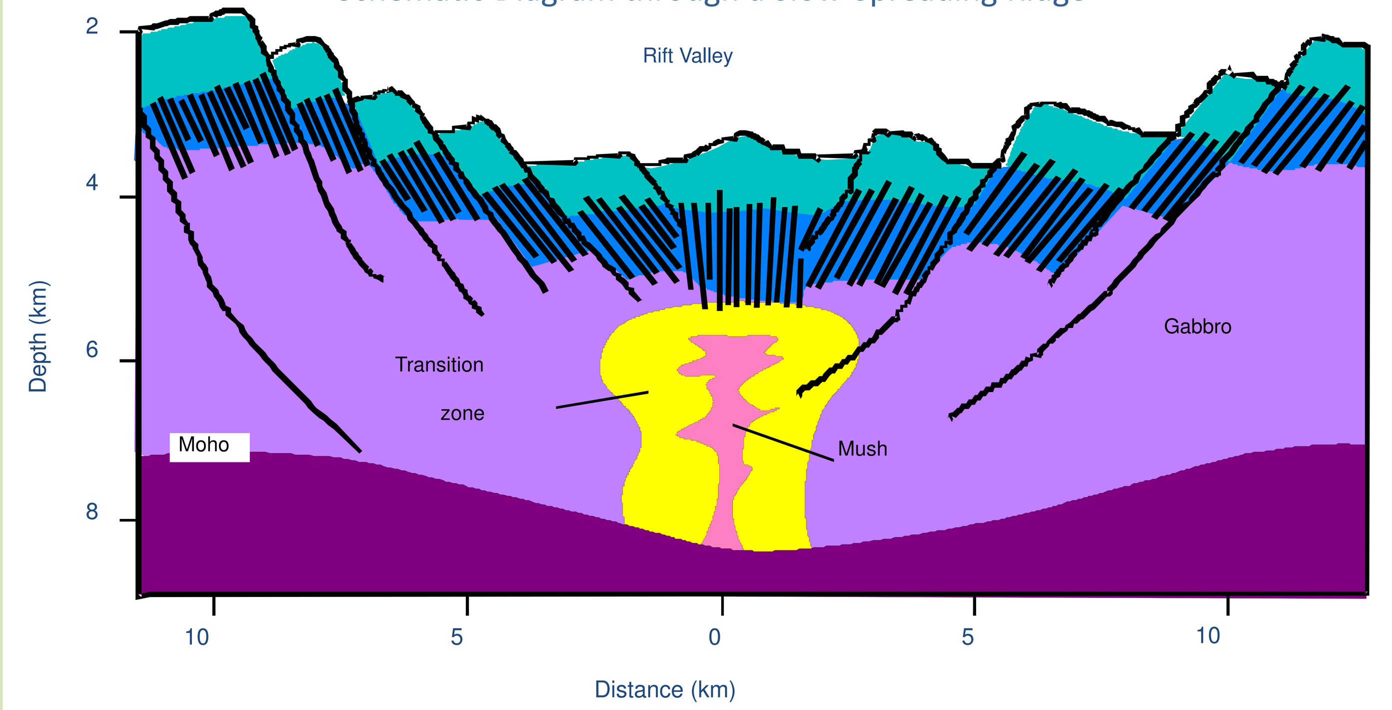
After groups have organized the rocks according to relative density and identified as many as possible, I ask for volunteers to report back to the class. The sediment and basalt are easily identified as the less dense samples, but gabbros and peridotites have similar density and can be easily mistaken. At this point I spend a few minutes talking about ophiolite sequences and showing photos from the Franciscan Complex, CA or Macquarie Island (far South of New Zealand).

Schematic Cross-Section of Oceanic Crust

Lithology	Ocean Crustal Layers	Typical Ophiolite Thickness (km)	Normal Ocean Crust Thickness (km) ave.	Normal Ocean Crust P wave vel. (km/s)
Deep-Sea Sediment	1	~ 0.3	0.5	1.7 -2.0
Basaltic Pillow Lavas	2A & 2B	0.5	0.5	2.0 - 5.6
Sheeted dike complex	2C	1.0 - 1.5	1.5	6.7
Gabbro	3A	2 - 5	4.7	7.1
Layered Gabbro	3B			
Layered peridotite	4	up to 7		8.1
Unlayered tectonite peridotite				

From Winter, 2001, after Brown and Mussett (1993)

Schematic Diagram through a Slow-Spreading Ridge



From Winter, 2001, after Sinton and Detrick (1992)

I like to end the discussion with this cross-section through a mid-ocean ridge. Even though it is a schematic diagram, it combines observations that students have made from Google Earth, the block diagrams of fast and slow spreading ridges and it incorporates the different rock types they have identified. If, during previous discussions the class had not come to the conclusion that fast and slow spreading ridges were primarily controlled by competition between magmatism and faulting, this diagram may be useful for discussing these dual processes. The presence of the magma chamber in the diagram can help students visualize changes in size of magma chamber and buoyant rise of partially molten material. I haven't tried this, but one could ask the students to make a cross-sectional sketch of a fast spreading ridge to contrast with this slow-spreading example.

Finally, I end the class by talking about ridge-push and slab pull and tying mid-ocean ridges into a slightly larger tectonic context.

<u>REFERENCES:</u>

Brown, G.C. and Mussett, A.E., 1993, The Inaccessible Earth: An Integrated View of Its Structure and Composition: London, Chapman and Hall, 276 p.

Macdonald, K.C., 1982, Mid-ocean ridges: Fine scale tectonic, volcanic and hydrothermal processes within the plate boundary zone: Annual Review of Earth and Planetary Sciences, v. 10, p. 155-190.

Moores, E. M., and Twiss, R. J., 1995, Tectonics: New York, W.H. Freeman and Company, 415 p.

Sinton, J.M., and Detrick, R.S., 1992, Mid-ocean ridge magma chambers: Journal of Geophysical Research, v. 97, p. 197-216.